

## Performance of Bt. (*Bacillus thuringiensis*) cotton—A real time crop evapotranspiration based fertigation approach

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### ABSTRACT

*Bacillus thuringiensis* (Bt) cotton hybrid was used as test material to conduct an experiment during *kharif* 2020 and 2021 in split plot design with three replications to evaluate the fertigation levels. Four irrigation levels, viz. drip irrigation at 1.0, 0.8 and 0.6 Crop Evapotranspiration ( $ET_c$ ), and Conventional Method (CM) of irrigation as main plot while, sub-plot treatments consisted four nutrient levels, viz. Recommended dose of fertilizers (RDF) 175:60:60 (N:P:K), 75% of RDF, 50% of RDF and Control. Significantly higher seed cotton yield was recorded under drip irrigation at 1.0  $ET_c$  (2.42 and 1.42 t/ha) and 0.8  $ET_c$  (2.38 and 1.40 t/ha) over conventional method (CM) of irrigation (2.23 and 1.27 t/ha) during 2020 and 2021, respectively. The highest bolls per plant (36.5) were produced under drip irrigation at 1.0  $ET_c$  which were statistically similar to drip irrigation at 0.8  $ET_c$  and CM; which were significantly higher than at 0.6  $ET_c$  during 2020. Seed cotton yield produced at RDF (2.60 and 1.62 t/ha) and 75 % of RDF (2.53 and 1.59 t/ha) were statistically similar but significantly higher than 50% RDF (2.33 and 1.35 t/ha) and control (1.72 and 0.72 t/ha) during 2020 and 2021. The total irrigation water use in Bt. cotton was reduced by 13.8-15.1 and 8.6-9.5 per cent while WUE increased by 24.7 and 18.6 percent under drip irrigation at 0.8 and 1.0  $ET_c$ , respectively, in comparison to CM. The highest net returns were recorded under nutrient levels @ 75% of RDF under drip irrigation at 1.0  $ET_c$  followed by 0.8  $ET_c$ .

**Key words:** Cotton, Drip fertigation, Evapotranspiration, Productivity, Profitability, Water use efficiency

Cotton (*Gossypium hirsutum* L.) is a leading fiber and cash crop of the world that is grown commercially for agricultural and industrial purposes in the tropical and subtropical regions of more than fifty countries. India is the second largest cotton producer country after China. India has the distinction of having the largest area (12.69 million hectares) under cotton cultivation and production is 325.2 lakh bales of 170 kg with an average yield of 436 kg/ha which is lower than the global average yield (808 kg/ha) of cotton during 2023-24 (Anonymous, 2023). The cotton crop is a good source of employment for the rural community. It contributes for value addition in agriculture and fetches a substantial amount of foreign exchange through exportable surplus of cotton fiber and fiber made products.

Land and water are the basic needs for agriculture, infrastructure and economic progress of any country. According to International Water Management Institute (IWMI) report, one-third of the world's population will

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face absolute water scarcity by the year 2025 (IWMI, 2006). More than 80% of the exploitable water resources are utilized for irrigation purpose in agriculture. It indicates that overall development of the agriculture sector is largely dependent on the proper and judicious use of the available water resources.

Drip irrigation is an efficient method of providing irrigation water directly into soil at the root zone of plants to minimize conventional losses such as deep percolation, runoff and soil erosion. Unlike surface irrigation, drip irrigation is more suitable and economical if it is introduced in water scarce areas, shallow and sandy soils and for wide spaced high value crops. The most of the area of south-west Haryana is categorized as rainfed with average rainfall 350-400 mm, sandy soils with poor fertility, low organic carbon and less water holding capacity. In this region the cotton crop is grown in *kharif* season sown in the month of April-May which takes 160-175 days to mature. The area under cotton crop in this zone of state is continuously increasing due to higher returns but the irrigation water availability is also scanty in these areas. On the basis of different findings Vaddula and Singh (2023) concluded that drip fertigation could save 20-30% fertilizer

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and around 50-60% of water besides improving cotton yield. However, despite distinguished advantages, its adoption is limited in most of developing countries with the main impediment being the high initial investment. Secondly, variability in rainfall pattern with uneven distribution, soil type, crop variety and management levels are also affecting seed cotton yield adversely (Bhaskar, 2004). Pawar *et al.* (2015) identified the benefits of micro-irrigation in terms of water saving and productivity gains are substantial in comparison to the cotton crops cultivated under flood method of irrigation. Micro-irrigation is also found to be reducing energy (electricity) requirement, weed problems, soil erosion and cost of cultivation.

Under such circumstances, effective management of available water is of utmost importance for cotton cultivation under rainfed conditions and that could be made possible through drip irrigation system. Fertilizer application through drip-irrigation (fertigation) can enhance the production per unit input in the nutrient poor, shallow and light soils. Keeping all these in view, the present study was designed to study the extent of benefits derived from fertigation in cotton crop.

## MATERIALS AND METHODS

### Experimental site details

A field experiment was conducted during *kharif* 2020 and 2021 at Regional Research Station, Bawal (Rewari), Haryana, India situated at 28.1° N latitude and 76.5° E longitude at an elevation of 266 meter above mean sea level with sub-tropical climatic conditions. Soil of the experimental field was categorized as loamy sand in texture, with low in Organic Carbon, available Nitrogen and phosphorous, while medium in K. Peculiar characteristics of Bawal region are semi- arid climate with hot sunny days along with dry winds during summer and severe cold days during winter. Mean maximum temperature reaches as high as 48°C and mean minimum temperature reaches as low as 2°C. Sometimes minimum temperature touches the freezing point. South-west monsoon season i.e., from July to September contributes around 80% of the total annual rainfall. Western disturbances also cause significant amount of rainfall during winter months. The total rainfall was 380 mm during *kharif* 2020 and 907 mm during *kharif* 2021. The mean weekly weather data are given in Fig. 1 and 2.

The soil properties and nutrient status of experimental field before sowing of crop during *kharif* 2020 are as given

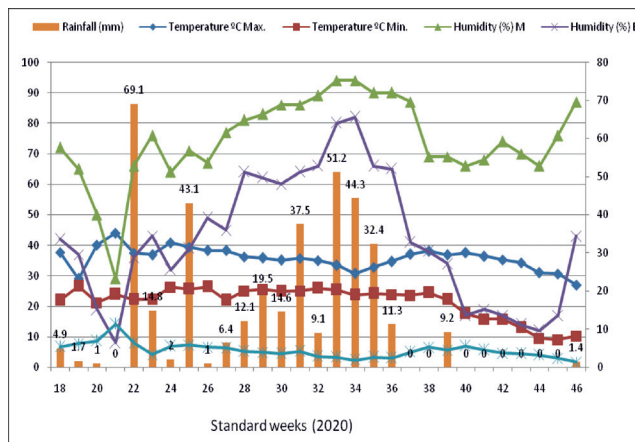


Fig. 1. Meteorological data during the crop season during *kharif* 2020

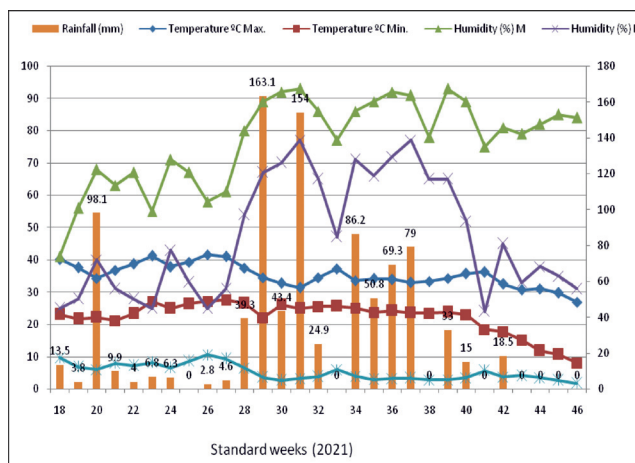


Fig. 2. Meteorological data during the crop season during *kharif* 2021

in Table 1 The quality of irrigation water applied was under good category having pH (1:2) 7.9, EC 1.72  $\text{ds m}^{-1}$  and SAR 7.6 ( $\text{mmol}^{-1}$ )<sup>1/2</sup>.

### Treatments details

Crop Bt. Cotton hybrid RCH 776 was sown on May 6 and April 18 during 2020 and 2021, respectively after applying pre-sowing irrigation. The experiment was laid out in split plot design with three replications. The main plot treatments comprised of four irrigation levels, viz. drip irrigation at 1.0, 0.8 and 0.6 Crop Evapotranspiration ( $\text{ET}_c$ ), and Conventional Method (CM) of irrigation i.e. Flooding with 6 cm water depth. The sub- plots treatments consisted

Table 1. Soil properties and nutrient status of experimental field before sowing of crop in 2020

pH (1:2)	EC (ds/m)	OC (%)	Available N (Kg/ha)	Available P (Kg/ha)	Available K (Kg/ha)
7.50	0.19	0.20	114.0	9.80	172.4

of four levels of fertilizer, *viz.* Recommended dose of fertilizers (RDF) 175:60:60 (N:P:K), 75% of RDF (131:45:45), 50% of RDF (87.5:30:30) and Control (No fertilizer). The total treatment combinations were 16.

#### Nutrient application

The nutrients were supplied on the basis of recommendation of state agricultural university i.e. nitrogen (N), phosphorus (P), Potash (K) and Zinc sulphate (Zn) at the rate of 175, 60, 60, 25 kg/ha, respectively. The fertilizers under drip irrigation treatments, one-tenth (10%) of the recommended N, P and K and full Zn was applied to the experimental plots before sowing of cotton seed and rest of the nutrients were applied through fertigation as per treatment in 6 splits at an interval of 15 days. Fertigation (except in CM) was implemented at the first irrigation i.e., 30 days after sowing (DAS) and continued up to the boll formation stage (120 DAS). The fertilizer used in fertigation application was 47 kg of soluble mixture of NPK (19-19-19) and remaining nitrogen quantity was added with urea (37.5 kg) per hectare and applied using venture method (Cetin and Akalp, 2019). Fertilizer application under conventional method of irrigation (RDF-175, 60, 60, 25 kg ha<sup>-1</sup> NPK Zn, respectively), whole Phosphorous, potash and zinc sulphate was drilled as basal dose, while half of the recommended dose of nitrogen was applied at square formation and remaining half was applied at 50% flowering stage of crop through broadcasting methods before irrigation application.

#### Cultivation practices

The crop was sown at a row spacing 100 cm and plant to plant distance was maintained at 45 cm. Gross plot size was 4.0 m × 9.0 m (36.0 m<sup>2</sup>) while the net plot area taken was 2.2 m × 7.2 m (14.4 m<sup>2</sup>) for final data purpose. The sowing of crop was done by dibbling method. The plant population was maintained in all the plots by thinning and gap filling as required. One intercultural tillage at 25 days after Sowing (DAS) and one hand weeding at 45 DAS was done to control the weeds. Fertilizers were applied as treatment. Soil sampling was done at the time of sowing before application of basal dose of fertilizers and at the time of harvesting of crop.

#### Estimation of crop evapotranspiration and irrigation scheduling

For the estimation of crop evapotranspiration (ET<sub>c</sub>) based on the FAO-56 Penman-Monteith (PM) method, the climatologically data were used from the automatic climatological station near the experimental site. The drip irrigation scheduling was performed at an interval of 4 days based on the ET<sub>c</sub> (Uzen and Citin, 2016). The crop coeffi-

cient (K<sub>c</sub>) approach was used for the estimation crop ET<sub>c</sub>, and the equation given below was used to calculate crop ET<sub>c</sub> (Allen *et al.*, 1998):

$$ET_c = K_c \times ET_o$$

...where ET<sub>c</sub> is the estimation of crop evapotranspiration (mm d<sup>-1</sup>), K<sub>c</sub> is the crop coefficient for cotton and ET<sub>o</sub> is the reference crop evapotranspiration (mm d<sup>-1</sup>). K<sub>c</sub> values concerning the crop development stages (initial stage, crop growth stage, boll development stage (mid-season), and maturity stage (last season) of cotton in the study were derived/computed from the publication of FAO-56 considering the long-term climatological data in the study area (last 30 years). Thus, the K<sub>c</sub> values considered were 0.45, 0.75, 1.15, and 1.00 for the initial stage (0-25DAS), growth stage (26-75 DAS), boll development (76-120 DAS), and maturity stage (>126 DAS), respectively. The drip irrigation was stopped 15 days before last picking. The irrigation in conventional method was applied through flooding as per recommendation of state agricultural university.

#### Water use and water use efficiency

The total water used during the whole crop cycle was calculated as follows:

$$WU = I + R + \Delta w$$

..... Where, WU = water used in the whole crop cycle, I = irrigation water applied (mm), R = effective rainfall, and “w is the difference in terms of water content in the soil layer explored by roots at sowing and harvesting time, measured gravimetrically.

The water use efficiency (WUE) in kg/ha-mm for a given treatment was calculated by dividing the seed cotton yield with the respective total water used by the crop.

$$WUE \text{ (kg/ha-mm)} = \frac{\text{Seed yield (kg/ha)}}{\text{Total water use (mm)}}$$

#### Observations

The observations were recorded on plant population, plant height, number of monopodia and sympodia, number of bolls per plant, boll weight (g) etc. at the time of harvest from five randomly selected and tagged plants from each treatment. The seed cotton yield (kg) picked manually from the central two rows of each plot twice during the cropping seasons. The first picking was made at about 80% of the opened bolls, and the second was made for the rest of opened bolls in the middle of September and beginning of October, respectively. The yields obtained from the harvested area were converted to the unit land area (ha) for all calculations and evaluations.

#### Statistical Analysis

Data collected during the study were statistically analyzed using the technique of analysis of variance

(ANOVA) described by (Cochran and Cox, 1959). To judge the significant difference between means of two treatments, the critical difference (CD) was used. The 'OPSTAT' (Sheoran *et al.*, 1998) software of CCS Haryana Agricultural University, Hisar, India was used for statistical analysis.

## RESULTS AND DISCUSSION

The yield attributing character *viz.* branches/plant (monopodial and sympodial) and boll weight were not influenced significantly by irrigation levels and methods during 2020 but the sympodial branches were significantly higher under drip irrigation at 1.0 and 0.8 ET<sub>c</sub> as compared to 0.6 ET<sub>c</sub> and CM during 2021. This might be due to plant exposes to moisture stress under irrigation at 0.6 ET<sub>c</sub>. The number of bolls per plant (36.5) produced under drip irrigation at 1.0 ET<sub>c</sub> was statistically at par with drip irrigation at 0.8 ET<sub>c</sub> and CM, and significantly higher than the drip irrigation at 0.6 ET<sub>c</sub> during 2020, while in 2021 was similar under all methods of irrigation (Table 1). The findings are in agreement with Prajapati and Subbaiah (2018) who recorded improved bolls per plant under drip irrigation over the furrow method. The boll weight was not significantly influenced by any method of irrigation, however numerically higher boll weight was observed under drip irrigation at 0.8 ET<sub>c</sub> (Table 2) during both the years.

Growth as well as yield parameters *viz.*, plant population, branches/plant, bolls/plant and boll weight was increased with increase in fertilizer levels in comparison to control. All parameters were statistically similar under fertigation of 100% RDF and 75% of RDF which were significantly higher than 50% of RDF and control during both

years (Table 2). Similarly, Gawali *et al.* (2020) reported that the growth and yield component like plant height, number of leaves, leaf area, number of bolls, seed and stalk yield of cotton were significantly improved with application of 100 per cent RDF by fertigation into six splits followed by 80% RDF.

Significantly higher seed cotton yield was recorded under drip irrigation at 1.0 (2.42 and 1.42 t/ha) and 0.8 (2.38 and 1.40 t/ha) ET<sub>c</sub> over conventional method (2.23 and 1.27 t/ha) of irrigation and 0.6 ET<sub>c</sub> (2.18 and 1.17 t/ha). However, the yield under CM was significantly higher than the yield recorded under drip irrigation at 0.6 ET<sub>c</sub> during both the years of experimentation (Table 3). The yield level was lower during the 2<sup>nd</sup> year of experimentation due to attack of pink boll worm which damaged around 60% of the matured bolls. Singh *et al.* (2021) also reported that drip irrigation in cotton scheduled at 0.8 ET<sub>c</sub> recorded 2.5 and 23.2% higher seed cotton yield (2.51 t/ha) than 1.0 ET<sub>c</sub> and 0.6 ET<sub>c</sub>, respectively. A combination of drip fertigation at 0.8 ET<sub>c</sub> and 100% RDN elucidated 11.6, 61.5, 13.9%, and 42.9% higher SCY, water use efficiency, nitrogen use efficiency and benefit: cost ratio than control, respectively.

Increase in yield might be attributed to better availability of not only moisture but nutrients also in the rhizosphere of plant. Yang *et al.* (2023) concluded on the basis of different studies that the when availability of irrigation water amount is more (100-120%), drip irrigation significantly increases the crop yields by 28.92%, 14.55%, 8.03%, 2.32%, and 5.17% relative to flooding irrigation, border irrigation, furrow irrigation, sprinkler irrigation, and micro-sprinkler irrigation, respectively. However, there was no significant difference in yield between drip irrigation and

**Table 2.** Effect of different irrigation methods, irrigation levels and fertigation on growth and yield attributes of Bt. Cotton

Treatment	Plant Popn. (000/ha)		Branches/Plant				Bolls/Plant		Boll wt. (g)	
	2020	2021	Monopodial		Sympodial		2020	2021	2020	2021
			2020	2021	2020	2021				
<i>Irrigation Level</i>										
1.0 ET <sub>c</sub>	16.58	16.88	2.75	3.0	25.9	26.8	36.5	37.7	4.96	4.86
0.8 ET <sub>c</sub>	16.32	16.51	2.72	2.9	25.1	26.2	36.3	38.1	4.97	4.89
0.6 ET <sub>c</sub>	15.76	15.88	2.78	2.9	23.3	24.3	32.8	34.5	4.94	4.84
CM	15.16	14.95	2.72	3.0	23.4	24.5	34.3	35.9	4.97	4.87
CD (P=0.05)	NS	NS	NS	NS	NS	1.7	2.8	NS	NS	NS
<i>Nutrients level</i>										
RDF	16.55	16.55	2.95	3.3	27.4	28.8	37.3	39.3	5.06	4.96
75% of RDF	16.27	16.53	2.83	3.1	26.8	27.9	37.1	38.6	5.04	4.92
50% of RDF	15.83	15.86	2.61	2.9	23.0	24.0	34.8	36.2	4.93	4.84
Control	15.16	15.28	2.58	2.6	20.5	21.1	30.8	32.2	4.83	4.73
CD (P=0.05)	9.36	1.01	0.28	0.2	2.6	2.7	2.2	2.5	0.7	0.10

The interaction of fertilizer doses and irrigation methods for all the growth and biometric measurement was found non-significant

border irrigation or micro-sprinkler irrigation. Similar findings were reported by Singh *et al.* (2022)

The seed cotton yield under fertigation increased with the increasing dose of fertilizers. The seed cotton yield produced at RDF and 75% of RDF was statistically similar but significantly higher than 50% of RDF and control (Table 3). Enhancement in yield of cotton crop due to scientific scheduling of fertilizer through drip (5033 kg/ha) over conventional method i.e. soil application of fertilizer (4096 kg/ha) has been reported by Nalayini *et al.* (2012). Tandel *et al.* (2022) also reported the seed cotton at 100% NPK (4.24 t/ha) had recorded statistically at par with 80% NPK (3.93 t/ha) which were significantly higher than 60%

NPK (3.37 t/ha), applied through drip fertigation. Gawali *et al.* (2020) also reported improved seed cotton yield (3.62 t/ha) with application of 100 per cent RDF through soluble fertilizers by fertigation into six splits followed by 80% RDF (3.27 t/ha) through soluble fertilizers as compared to RDF through soil application (2.47 t/ha). Similar findings were reported by Singh *et al.* (2022).

The interaction effect of fertilizer doses and irrigation methods on Seed Cotton yield was found non-significant. (Table 4 and 5)

The water use efficiency of irrigation at 0.8 and 1.0 ET<sub>c</sub> level, where yield levels were statistically similar, was numerically higher under drip irrigation at 1.0 ET<sub>c</sub> during

**Table 3.** Seed cotton yield, water use and water use-efficiency as influenced by fertigation in Bt. cotton

Treatment	Seed cotton yield (t/ha)		Irrigation applied (mm)		Total water use (mm)		WUE (kg/ha-mm)	
	2020	2021	2020	2021	2020	2021	2020	2021
<i>Irrigation level</i>								
1.0 ET <sub>c</sub>	2.42	1.42	184.8	180	566.0	639.3	4.27	2.22
0.8 ET <sub>c</sub>	2.38	1.40	147.6	144	531.2	602.9	4.49	2.31
0.6 ET <sub>c</sub>	2.18	1.17	110.9	108	497.2	565.8	3.85	2.07
CM	2.23	1.27	240.0	240	625.4	699.6	3.57	1.81
CD (p=0.05)	0.14	0.10	-	-	-	-	-	-
<i>Nutrients level</i>								
RDF	2.60	1.62	170.6	168	552.9	626.9	4.71	2.59
75% of RDF	2.53	1.59	170.6	168	552.9	626.9	4.58	2.54
50% of RDF	2.33	1.35	170.6	168	552.9	626.9	4.21	2.15
Control	1.70	0.72	170.6	168	552.9	626.9	3.06	1.15
CD (p=0.05)	0.11	0.08	-	-	-	-	-	-

**Table 4.** Interaction table (fertilizer doses × irrigation methods) for seed cotton yield of cotton during 2021

	RDF	75% of RDF	50% of RDF	Control	Mean
1.0 ET <sub>c</sub>	2,722	2,677	2,497	1,767	2,416
0.8 ET <sub>c</sub>	2,707	2,693	2,433	1,703	2,384
0.6 ET <sub>c</sub>	2,433	2,363	2,265	1,653	2,179
CM	2,650	2,497	2,119	1,657	2,230
Mean	2,628	2,558	2,328	1,695	

Irrigation Methods × Fertilizer Doses = NS

**Table 5.** Interaction table (fertilizer doses × irrigation methods) for Seed Cotton yield of cotton during 2022

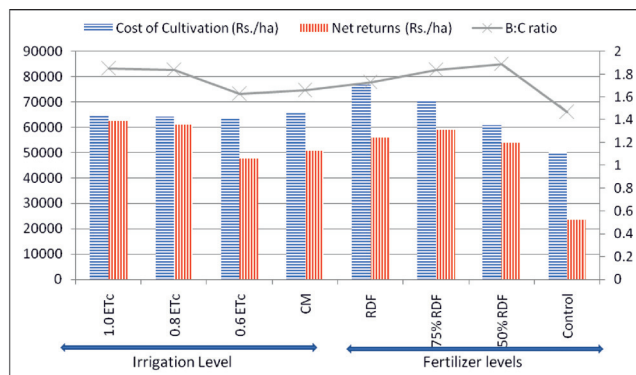
	RDF	75% of RDF	50% of RDF	Control	Mean
1.0 ET <sub>c</sub>	1,728	1,690	1,483	767	1,417
0.8 ET <sub>c</sub>	1,717	1,677	1,433	753	1,395
0.6 ET <sub>c</sub>	1,413	1,377	1,252	653	1,174
CM	1,637	1,497	1,233	700	1,267
Mean	1,624	1,560	1,350	718	

Irrigation Methods × Fertilizer Doses = NS

both the years. The total irrigation water used in Bt. cotton was reduced by 13.8-15.1 and 8.6-9.5 per cent while WUE increased by 24.7 and 18.6 percent under drip irrigation at 0.8 and 1.0 ET<sub>c</sub>, respectively, in comparison to conventional method of irrigation. The highest total water use was recorded under conventional method of irrigation (240 mm) followed by 1.0 ET<sub>c</sub> and 0.8 ET<sub>c</sub> (Table 3) during both the years. The study further reveals that 38-40% of total irrigation water applied under flooding can be saved through drip irrigation at 0.8 ET<sub>c</sub>. Tian *et al.* (2022) also reported 57.58% enhanced water productivity through drip irrigation compared to border irrigation in winter wheat. Drip irrigation was more efficient in terms of unit water productivity due to reduced water loss through seepage and evaporation compared to other methods of irrigation, (Flore *et al.*, 2021; and Fukai and Mitchell, 2022).

### Economics

The highest net return was found under fertigation @ 75% of RDF (Rs.59,159/-) while, among different irrigation levels the highest net return was recorded under drip irrigation @ 1.0 ET<sub>c</sub> (Rs.62,410/-) which was very close to 0.8 ET<sub>c</sub> (Rs.61,170/-). Highest cost of cultivation was recorded under conventional method of irrigation and at recommended dose of fertilizers (Fig. 1). Highest benefit: cost (BC) ratio was recorded under the treatment where fertigation was applied through drip method of irrigation at 1.0 ET<sub>c</sub> followed by 0.8 ET<sub>c</sub>. The findings are in close conformity to those of Singh *et al.* (2021) who elucidated higher net returns (33.5 and 3.5%) and cost: benefit ratio (26.1 and 1.8 %) under drip 0.8 ET<sub>c</sub> over that of 0.6 and 1.0 ET<sub>c</sub>, respectively in cotton. Panwar *et al.* (2015) revealed that drip irrigation system not only reduces cost of cultivation (25 %) but also increases the productivity (27.2 %) over furrow irrigation in cotton crop.



**Fig. 1.** Economics of cotton as influenced by fertigation (Average of two years)

### Available nutrient status

Fertigation leads to judicious use of fertilizers thereby reducing plant stress resulting into early harvests, superior crop quality, and enhanced yield uniformity. It affected soil fertility by increasing available N, available P and available K of soil compared to no fertilizers. The available N was increased when fertilizers applied through fertigation with 100% RDF and 75% of RDF, whereas, available P and K were increased under fertigation with 100% RDF, 75 and 50% of RDF; as compared to initial soil nutrients status (Table 4). The integration of irrigation and fertilization designs can enhance the nutrient use efficiency and drop the risk of nutrient loss (Toonsiri *et al.*, 2016). Flood method irrigation recorded less available nitrogen due to low nutrient use efficiency of fertilizers. These results are in conformity with Magare *et al.* (2018).

The present study shows that cultivating cotton under drip method of irrigation provides a number of benefits to farmers over flood irrigation method. The cost of irrigation to the tune of about 23% under drip method of irrigation.

**Table 7.** Available soil nutrient after the harvest of crop as influenced by fertigation in Bt. Cotton after two years of experimentation

Treatment	Available N (Kg/ha)	Available P (Kg/ha)	Available K (Kg/ha)
<i>Initial level</i>	114.0	9.80	172.4
<i>Irrigation level</i>			
1.0 ET <sub>c</sub>	110.11	10.88	174.58
0.8 ET <sub>c</sub>	112.83	11.16	175.15
0.6 ET <sub>c</sub>	112.24	11.38	176.23
CM	103.33	11.56	177.43
<i>Nutrient level</i>			
RDF	119.25	12.48	181.86
75% of RDF	114.35	11.46	177.44
50% of RDF	108.00	10.86	173.81
Control	96.90	10.18	170.28

Irrigation water saving due to the adoption of drip method of irrigation in cotton cultivation is estimated to be about 38-40%. The productivity difference between drip irrigated at 0.8 ET<sub>c</sub> and flood irrigated cotton comes to about 141 kg/acre, which is about 8.5% In Bt. cotton, drip irrigation at 0.8 ET<sub>c</sub> at 4 days interval and 75% dose of recommended fertilizers through fertigation was found best in terms of productivity, profitability and water use efficiency in loamy sand soils of south-west Haryana, and it was superior to conventional method of irrigation. The study further reveals that 25% of fertilizers can be saved through fertigation.

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