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Drip fertigation effects on yield, nutrient uptake and soil fertility of Bt Cotton in semi arid tropics

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Abstract

Field experiment was conducted for 2 seasons to study the influence of drip fertigation in combination with or without bio fertilizers on yield, plant uptake and soil fertility of Bt cotton. The treatments comprised of four levels of drip fertigation viz., 75, 100, 125 and 150 per cent of recommended dose of fertilizers (RDF, NPK) combined with and without bio fertilizers, drip irrigation with soil surface application of 100 per cent RDF and surface irrigation with soil surface application of 100 per cent RDF as control. Biofertilizers used for fertigation is azophosmet containing Azospirillum, phosphobacterium and pink pigmented facultative methylotroph. Most of the yield attributes *viz.*, number of sympodial branches per plant, number of fruiting points, bolls per plant, plant uptake and available soil N, P and K of Bt cotton were significantly increased by the drip fertigation treatments. Application of 150 per cent RDF as drip fertigation combined with biofertigation of liquid formulation of azophosmet @ 250 ml (10^{12} cells ml^{-1}) ha^{-1} registered the highest seed cotton yield of 3395 kg ha^{-1} and was significantly superior over control. Biofertigation significantly increased seed cotton yield and a progressive increase in seed yield was noticed with increasing levels of NPK fertilizer application. Application of nutrients through drip fertigation improved seed cotton yield by 43.0 per cent compared with conventional surface irrigation with soil surface application of fertilizers. The nutrient uptake pattern and post harvest soil fertility status also followed similar trend and confirmed the significance of drip fertigation with biofertilizers.

Keywords: Available soil nutrients; Cotton; Plant uptake; Yield attributes and yield.

Introduction

Cotton is an important commercial crop of India, grown by four million farmers in an area of 7.4 million hectares. India occupies the foremost position in acreage, which is almost 25% of the global cotton area. Cotton enjoys a predominant position amongst all cash crops in India. Cotton is an important raw material for the Indian textile industry, constituting about 65 per cent of its requirements. The Indian textile industry occupies a significant place in the country's economy with over 1500 mills, 4 million handlooms, 1.7 million power looms and thousands of garment, hosiery and processing units, providing employment directly or indirectly to around 35 million people (Sankaranarayanan et al., 2011).

However, the productivity of cotton is very low in India and its production contribution is only 9% compared with 22% in China and 19.4% U.S (FAO, 2009). The lint productivity of cotton is 322 kg ha^{-1}, which is the lowest and far below that of the world average of 627 kg ha^{-1} (Shivagaje et al., 2004). Excessive vegetative growth, boll shedding, imbalanced use of organic and inorganic fertilizers and poor agronomic practices largely attribute to low productivity of cotton in India. A nutrient budgeting study on cotton showed that the calculated nutrient balances of N and K were negative and that has the implications of low yield of cotton (Surendran and Murugappan, 2006). With advancement in evolving superior hybrids and production technologies, the cotton cultivation is gaining momentum and there exists potential scope for enhancing its productivity.

Agriculture is by far the largest (81%) water consumer in India (WRI, 2007) and hence more efficient use of water in agriculture needs to be the top most priority. Water input per unit irrigated area will have to be reduced in response to water scarcity and environmental concerns (INCID, 2006). It has been scientifically recognized that adoption of drip fertigation method is an option for efficient use of water and nutrients through improvement in crop yield per unit volume of water and nutrients used (Bar-Yosef, 1999; Patel and Rajput, 2011). A review of the current literature on the use of fertigation by Jat et al. (2011) from ICRISAT, suggests that to make agriculture sustainable and economically viable, there is need to promote fertigation on a large scale by the concerned stakeholders / farmers.

Although the use of chemical fertilizer is the fastest way of counteracting the pace of nutrient depletion, its increasing cost and limited availability, discourage the farmers from using these inputs in balanced proportions thereby paving way for the problems of environmental pollution. Because of dwindling phosphate reserves and soaring prices for phosphate fertilizer (Van Vuuren et al., 2010), there is a renewed interest in the capability of biofertilizers to efficiently supply plant-available phosphorous in agricultural production systems (Surendran and Vani, 2013). Scientists are currently interested in developing alternative technology to minimize the dependence on chemical fertilizers and encourage the other viable options on a large scale by the farming communities (Surendran and Vani, 2013). Under this context, practice of integrated nutrient management comprising integrated usage of chemical fertilizers and other source of organic manures such as biofertilizers will result in sustainable crop yields without any detrimental effect on agro ecological balance. Bio fertigation which is the efficient and precise use of beneficial microorganisms through drip irrigation is the novel method for sustaining productivity. Since liquid formulations of various forms of biofertilizers are of recent introduction, hence the studies on bio fertigation is very limited. More results are needed for clear trends to emerge and to decide whether we can go for large scale application of bio fertigation by farmers in semi arid tropical agro ecosystem in India. Hence, with the above background the present investigation was carried out to study the effect of drip fertigation in conjunction with biofertilizers on the productivity of Bt cotton hybrid.

Materials and Methods

Study area

The study area of Coimbatore district is located in the Western agro-climatic zone of Tamil Nadu in the southern part of India and site characteristics are presented in Table 1a along with the weather parameters observed during the growing season. The soils of the experimental fields were analyzed for their physico-chemical properties and are also presented in Table 1b along with the site characteristics. A field experiment was conducted for 2 consecutive years at Agricultural College and Research Institute, Coimbatore during winter, to study the effect of drip fertigation in combination with bio fertilizers on growth and yield of Bt cotton.

Table 1. Characteristics of the study area.

1a.Site characteristics	
Districts	Coimbatore
Latitude/Longitude	8° 5' and 13° 36' N latitude and between 76° 15' and 80° 20' E longitude
Elevation (above mean sea level) (m)	427
Mean annual maximum Temperature (°C)	31.25
Mean annual minimum Temperature (°C)	20.45
Mean annual Rainfall (mm)	628
Major soils	*Alfisols, Vertisols*
Major crops grown	Sugarcane (*Saccharum officinarum),* Banana (*Musa paradisiaca),* Turmeric (*Curcuma longa*), Cotton (*Gossypium Spp*), Maize (*Zea mays*), Sorghum (*Sorghum bicolor*), variety of pulses and vegetables
Preceding crop in the experimental plot	Maize (*Zea mays)*
Growing Period Weather Parameters	
Mean maximum Temperature (°C)	29.94
Mean minimum Temperature (°C)	22.38
Mean Rainfall (mm)	587
1 b. Soil characteristics	
Soil series	Periyanaickenpalayam
Texture	Sandy clay loam
pH	8.56
EC (dS m^{-1})	0.40
Organic carbon (%)	0.52
Available N (kg ha^{-1})	241.0
Olsen-P (kg ha^{-1})	19.0
Exchangeable K (kg ha^{-1})	459.0

Treatment details and crop management

The experiment was laid out with a set of ten treatments (Table 2) in randomized block design with three replications. Intraspecific cotton hybrid NCS 145 Bt (Bunny Bt) released from Nuziveedu seeds limited, Hyderabad was used as the test variety. The experimental field was ploughed using tractor drawn disc plough followed by tiller and leveled. Raised beds of 1.2 m width with furrows of 30 cm width and 15 cm depth were formed for drip fertigation treatments. In each raised bed, two rows of cotton were planted at the spacing of 90 cm with plant to plant distance of 60 cm. Drip irrigation system was installed from sub main and its inline laterals were laid at a spacing of 1.5 m with 4 lph emitters spaced at 60 cm such that one lateral could cover two rows and one emitter could cover two plants. Ridges and furrows were formed at 75 cm spacing for furrow irrigation. The recommended dose of fertilizer (RDF) for test variety of cotton is 90:45:45 kg of NPK ha^{-1}. Phosphorus was applied as basal as per treatments given in Table 2 by fertigation. Nitrogen and potassium were applied as per the treatment through fertigation as urea and muriate of potash, respectively, in 14 splits at seven days interval commencing from 14 DAS upto 110 DAS. For the treatments, T_9 and T_{10} which involves soil application of fertilizers, recommended dose of nitrogen in the form of urea and potassium in the form of muriate of potash were applied in three equal splits as basal, 40 and 60 DAS. The liquid formulation of azophosmet containing Azospirillum, phosphobacterium and pink pigmented facultative methylotroph (PPFM) was used for biofertigation @ 250 ml (10^{12} cells ml^{-1}) ha^{-1} diluted in 100 liters of water and injected through the drip irrigation system as per the treatment schedule. Biofertilizer solution was prepared in a container from which it was sucked by venturi assembly and allowed through the irrigation system at an interval of 15 days commencing from 15 DAS up to 75 DAS (5 times). Biofertilizer was applied through drip 2 days after fertigation.

Table 2. Treatment structure.

Sl.No	Treatment details
T_1	Drip fertigation with 75 per cent RDF of NPK
T_2	Drip fertigation with 75 per cent RDF of NPK and biofertigation of azophosmet
T_3	Drip fertigation with 100 per cent RDF of NPK
T_4	Drip fertigation with 100 per cent RDF of NPK and biofertigation of azophosmet
T_5	Drip fertigation with 125 per cent RDF of NPK
T_6	Drip fertigation with 125 per cent RDF of NPK and biofertigation of azophosmet
T_7	Drip fertigation with 150 per cent RDF of NPK
T_8	Drip fertigation with 150 per cent RDF of NPK and biofertigation of azophosmet
T_9	Drip irrigation and soil application of 100 percent RDF of NPK
T_{10}	Surface irrigation and soil application of 100 per cent RDF of NPK as control

Calculation of irrigation water requirement

Irrigation water requirement, was calculated with the help of CROPWAT Model by determining reference crop evapotranspiration (ET_o) using FAO Penman–Monteith equation since it is reported to provide values that are very consistent with actual crop water use data (Allen et al., 1998). Parameters used for calculation of ET_o are latitude, longitude and altitude of the station, maximum and minimum temperature (^oC), maximum and minimum relative humidity (%), wind speed (km/day) and sunshine hours. Daily ET_o estimates for 15 years statistical period were then used to calculate the average rates of evapotranspiration. The calculated "long-term averaged ET" values were subsequently used to calculate ET_o estimates for corresponding 10-day periods. Crop coefficient (K_c) for cotton was selected from FAO-56 (Allen et al., 1998). By multiplying K_c and ET_o for cotton crop evapotranspiration (ET_c) during the planting season was calculated. Irrigation water requirement was calculated using the difference between the actual crop evapotranspiration and effective rainfall besides, considering the irrigation efficiency;

$$NIR=WR-ER-Ge$$

Where,

ER-Effective rainfall; Ge–Ground water contribution from water table (not considered in the calculation as this is negligible);

$$GIR=\frac{NIR}{E}$$

Where:

GIR=Gross irrigation requirement in mm; NIR=Net irrigation requirement in mm

E=Irrigation Application efficiency

Application efficiency considered for drip irrigation is 90 and for surface irrigation it is 50 (Sivanappan, 1994). Drip irrigation has been practiced daily whereas the surface irrigation was done at the interval of 5 days once.

Data collection and analytical procedures

Yield attributes *viz.*, number of sympodial branches per plant, number of fruiting points, bolls per plant and boll weight of Bt cotton were recorded by adopting standard procedures. The seed cotton obtained from each harvest was weighed and yield of five pickings were accumulated and expressed in kg ha^{-1}. In order to analyze the influence of soil properties on agronomic performance and to assess the impact of integrated management on soil fertility, representative soil samples were taken from each field at initial stage and post harvest stage. Samples were taken from the cultivated soil layer (upper 15 cm), using a single auger and combining 12 samples evenly distributed over the field to one composite sample. The samples were air dried, crushed and gravel and other particles of more than 2 mm were removed with a sieve. The samples were analysed in the soil laboratory of Department of Agronomy, Tamil Nadu Agricultural University, for the parameters listed in Table 3. Nutrient analysis was limited to N, P and K only. Similarly stage wise plant samples have also been collected and kept for nutrient uptake pattern analysis. N, P and K content in plant parts were analyzed using standard analytical procedures and expressed as percentage on dry weight basis and computed to kg ha^{-1}. Similar procedures were adopted in the second season crop also.

Table 3. Analytical methods for soil and plant parameters.

Parameter	Method	Reference
Soil parameters		
Texture (sand, silt, clay)	Hydrometer	Day (1965)
Organic carbon	Wet Digestion	Walkley and Black (1934)
Hydrolysable N	Alkaline permanganate method	Subbiah and Asija (1956)
Olsen-P	Olsen method	Olsen et al. (1954)
Exchangeable K	Ammonium acetate extractable K	Stanford and English (1949)
Plant Nutrient uptake		
Total nitrogen	Micro-Kjeldahl's method	Bremner (1965)
Phosphorus	Triple acid digestion extract-Vanadomolybdo-phosphoric acid yellow colour method	Jackson (1973)
Potassium	Triple acid digestion extract-Flame photometer method	Jackson (1973)

Statistical analysis

Statistical analyses of the data were carried out according to randomized block design. The experimental data were pooled and the mean data for two years are subjected to statistical scrutiny as per methods suggested by

Gomez and Gomez (1984). All the parameters were subjected to analysis of variance (ANOVA) and the data were analyzed using AGRES statistical software by Tamil Nadu Agricultural University. Fisher's Least Significant Difference (LSD) was used to test the significant differences between the means, at probability level P≤0.05 using the ANOVA. The non-significant treatment differences were denoted as NS.

Results and Discussion

Yield components

Adoption of drip fertigation with 150 per cent recommended NPK and biofertigation (T_8) recorded higher number of sympodial branches (18.1), fruiting points (68.5), number of bolls (29.5) and boll weight (4.8 g boll^{-1}) than the other treatments (Table 4). It was followed by fertigation with 150 per cent recommended NPK (T_7) and drip fertigation with 125 per cent recommended NPK and biofertigation (T_6) which were on par. Surface irrigation and soil application of 100 per cent NPK (T_{10}) resulted in the least sympodial branches, fruiting points, number of bolls and boll weight. The increase in yield attributes under drip fertigation might 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. Similar findings were also recorded by Grieesha (2003).

Seed yield

Application of varying levels of fertilizer as fertigation in combination with biofertigation of azophosmet positively influenced the seed yield (Table 4). Drip fertigation with 150 per cent recommended dose of NPK and biofertigation (T_8) recorded the highest seed yield of 3395 kg ha^{-1}. However, fertigation at 150 per cent recommended NPK with and without biofertilizer and application of 125 per cent NPK with biofertigation of azophosmet produced comparable yield and were superior over the rest of the treatments. Soil application of recommended NPK under surface irrigation and soil application of nutrients with drip irrigation produced yields on par with drip fertigation of 75 per cent recommended NPK and were significantly inferior over the other treatments.

Table 4. Effect of drip fertigation and biofertigation on sympodial branches, fruiting points plant^{1}, number of bolls plant^{-1}, boll weight, seed cotton yield and harvest index of Bt cotton. (Mean data for two years).

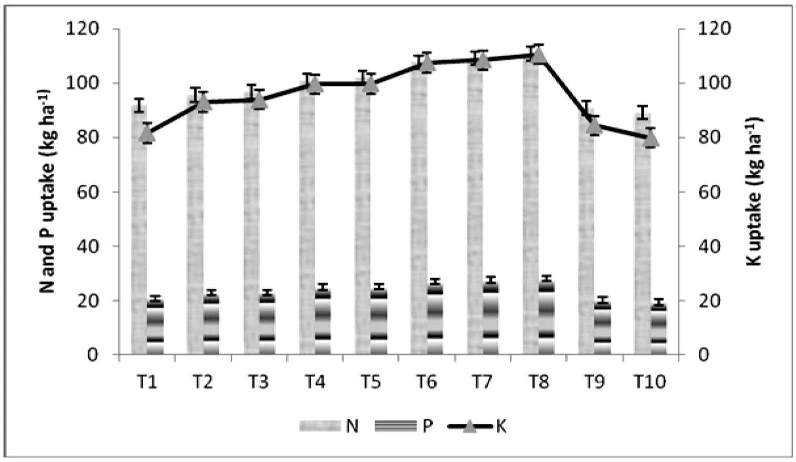
Treatments		Sympodial branches per plant	Fruiting points plant^{-1}	Number of bolls plant^{-1}	Boll weight (g boll^{-1})	Seed yield (kg ha^{-1})	Harvest Index
T_1:	DF with 75 per cent NPK	11.69	55.86	21.73	4.69	2036	0.41
T_2:	DF with 75 per cent NPK + biofertigation	13.66	57.27	22.92	4.83	2308	0.42
T_3:	DF with 100 per cent NPK	14.08	57.77	23.42	4.55	2353	0.41
T_4:	DF with 100 per cent NPK + biofertigation	15.68	59.80	25.30	4.69	2744	0.44
T_5:	DF with 125 per cent NPK	15.97	61.13	26.23	4.34	2829	0.45
T_6:	DF with 125 per cent NPK + biofertigation	17.57	66.82	28.90	4.97	3217	0.47
T_7:	DF with 150 per cent NPK	17.77	67.49	29.11	4.94	3273	0.48
T_8:	DF with 150 per cent NPK + biofertigation	18.08	68.45	29.47	4.84	3395	0.49
T_9:	DI + soil application of 100 percent NPK	11.33	55.77	21.33	4.90	1993	0.40
T_{10}:	SI + soil application of 100 per cent NPK	11.17	54.83	20.56	4.76	1934	0.39
SEd		0.81	1.07	0.69	0.22	125	0.01
LSD (P=0.05)		1.72	2.25	1.46	NS	262	0.01

Application of nutrients through drip fertigation improved seed yield by 43.0 per cent compared with conventional surface irrigation with soil application of fertilizer. Previous studies elsewhere have shown that drip and sprinkler irrigation increased seed yield of cotton compared with dryland cotton yield (Camp et al., 1997; Bronson et al., 2001; Pringle and Martin, 2003; Sorensen et al., 2004; Kalfountzos et al., 2007). Increased nutrient availability and absorption by the crop at the optimum moisture supply coupled with frequent nutrient supply by fertigation and consequent better formation and translocation of assimilates from source to sink might have increased seed yield under fertigation. Application of fertilizer nutrients through irrigation systems (fertigation) has been found to increase seed yield of cotton, water use efficiency and nutrient uptake by researchers in Syria (Janat and Somi, 2001; Janat, 2004), Texas (Enciso-Medina et al., 2007) and India (Thind et al., 2008). Irrigation systems permit multiple small dose fertilizer injections at different intervals, reducing the risk of leaching compared to fertilizers applied in a single application.

Comparatively lower seed yield of cotton under furrow irrigation with soil application of nutrients might be attributed to decrease in synthesis of metabolites and reduction in absorption and translocation of nutrients from soil to plant. The physiological response of plants by decreased cell division and cell elongation under moderate moisture stress at wider irrigation intervals might have also contributed to reduced cotton yield under furrow irrigation. The results are in conformity with the findings of Bharambe et al. (1997) and Veeraputhiran et al. (2002).

Nutrient uptake

Drip fertigation and its combination with biofertigation had a positive effect on N, P and K uptake at 120 DAS (Figure 1a). Drip fertigation with 150 per cent recommended dose of NPK and biofertigation (T_8) was significantly superior with the highest N, P and K uptake of 110.9, 28.2 and 110.6 kg ha^{-1} at 120 DAS, respectively. However, the effect of drip fertigation with 150 per cent recommended dose of NPK (T_7) and drip fertigation with 125 per cent recommended NPK and biofertigation (T_6) were statistically on par with drip fertigation of 150 per cent recommended NPK and biofertigation (T_8). Significantly lower N, P and K uptake of 89.2, 19.5 and 79.8 kg ha^{-1}, respectively was observed under surface irrigation with soil application of 100 per cent NPK (T_{10}).



Mean data for two years

	N	P	K
SEd ±	1.69	0.82	4.14
CD (P≤0.05)	3.55	1.73	8.70

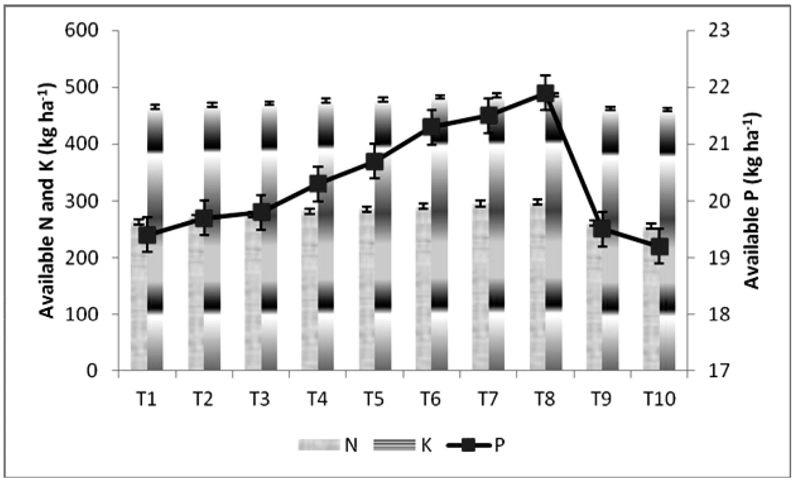
Figure 1a. Effect of drip fertigation on nutrient uptake.

The nutrient uptake was higher under increased levels of fertigation compared to surface irrigation with soil application of fertilizers. The N uptake was significantly higher under drip fertigation with 150 per cent recommended NPK compared with surface irrigation. The P and K uptake values followed more or less the similar trend as that of N uptake. The concentration and availability of various nutrients in the soil for plant uptake depends on the soil solution phase which is mainly determined by soil moisture availability. The higher available soil moisture provided due to continuous water supply under drip fertigation had led to higher availability of nutrients in the soil and thereby increased the nutrient uptake by the crop. The increased nutrient uptake under drip fertigation was the result of increased biomass production due to continuous availability of water and nutrients to the crop. The increased uptake may also be due to split application of N and K under drip fertigation that resulted in minimal loss of nutrients thereby making them available continuously to the crop. The application of fertilizer through drip fertigation than soil application produced significantly higher yield (Tumbare et al., 1999). Higher yield under fertigation is due to more nutrient uptake, fertilizer utilization efficiency and percentage of nutrient derived from fertilizer as compared with soil application (Mohammad, 2004). Radin et al. (1992) reported 40% increase in cotton lint yield under daily drip irrigation as compared with 10 or 14 day interval check-basin irrigation. They concluded that high frequency drip irrigation (1–2 day intervals) prevented cyclic water stress and deterioration of the root system compared with low frequency (2 weeks intervals), which might ultimately lead to higher nutrient uptake. Similar findings of higher nutrient uptake with drip fertigation of nutrient were reported by Bharambe et al. (1997) and Veeraputhiran (2000).

Post harvest soil available nutrient status

In general an increase in soil available NPK at post harvest was noticed as compared with initial soil nutrient status (Figure 1b). The treatments showed significant influence on post harvest soil available nutrient status and the highest NPK values were noticed under drip fertigation with 150 per cent recommended dose of NPK and biofertigation. This was comparable with drip fertigation at 150 per cent NPK and fertigation with 125 per cent NPK and biofertigation. Surface irrigation with soil application of 100 per cent NPK recorded the lowest values of post harvest soil available nutrients. The post harvest available nutrient status of the soil followed a similar trend as that of nutrient uptake pattern. The distribution and availability of nutrients in the soil depends upon their solubility, moisture and its variation.

The reason for higher post harvest available N, P and K in soil under drip fertigation could be due to reduction in leaching loss and better movement of nutrients in the soil under drip fertigation as compared with surface irrigation. Slight improvement in the post harvest soil fertility levels of N, P and K were noticed in biofertigation plots. This confirmed that biofertilizers solubilise the unavailable phosphorus to available P form and increase the P use efficiency. Inclusion of biofertilizers in the nutrient management programme has found to increase the yield of crops by 5-10%, besides increasing the nutrient use efficiency. Supply of water at shorter intervals and N and K supply through drip irrigation created a favorable condition rendering more nutrients available in the soil. Increasing the soil nutrient availability with drip fertigation as compared with soil application was reported by Malik et al. (1994) and Bharambe et al. (1997).



Mean data for two years

	Hydrolysable -N	Olsen-P	Exchangeable K
SEd ±	10.2	0.9	9.2
CD ($P \leq 0.05$)	21.4	1.9	19.4

Figure 1b. Effect of drip fertigation on post harvest soil nutrients.

Conclusions

The results of the present field investigations revealed that application of 150 per cent of recommended NPK as drip fertigation combined with the biofertiagtion of azophosmet @ 250 ml (10^{12} cells ml^{-1}) diluted in 100 litres of water ha^{-1} was found to be the viable agro technique to realize the yield potential of Bt cotton. To conclude, under semi arid tropic conditions drip fertigation with fertilizers and bio fertilizers will aid in easy application of amount and concentration of nutrients suited to the crop according to its stage of development, reduction in salinization, decrease in fluctuation of nutrient concentrations in soil during the crop growing season, higher fertilizer use efficiency and improved crop productivity.

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