EFFECT OF CONVENTIONAL AND WATER SOLUBLE FERTILIZERS THROUGH FERTIGATION ON GROWTH, YIELD AND QUALITY PARAMETERS OF Bt COTTON

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By

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CERTIFICATE

This is to certify that the thesis entitled " **EFFECT OF CONVENTIONAL AND WATER SOLUBLE FERTILIZERS THROUGH FERTIGATION ON GROWTH, YIELD AND QUALITY PARAMETERS OF Bt COTTON**" submitted by **Mr. PRADESH JENA.**, for the degree of **MASTER OF SCIENCE (AGRICULTURE)** in **AGRONOMY** to the University of Agricultural Sciences, Dharwad is a record of research work carried out by him during the period of his study in this university, under my guidance and supervision, and the thesis has not previously formed the basis for the award of any degree, diploma, associateship, fellowship or other similar titles.

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1. INTRODUCTION

Cotton the 'king of the fibre', as it is often referred to, still holds its position high. It provides the main raw material for textile industry and employment to several million people involved in cultivation, trade, processing, manufacturing and marketing. India has unique place among the cotton growing countries of the world. All the four lint bearing *Gossypium* spp. *viz*., *G. hirsutum, G. harbaceum, G. arboreum* and *G. barbadense* are grown in India under diverse agro climatic conditions and contribute nearly 65 per cent of total raw material needs of the textile industry (Jayakumar *et al.*, 2014). Presently the area under cotton in India is about 118 lakh ha accounting to 33 per cent of the world cotton area and stands second in production (352 lakh bales) next to China with average productivity of 503 kg lint ha^{-1}. Among the cotton growing states, Karnataka ranks sixth in both area 5.16 lakh ha and production 18.90 lakh bales of lint with an average productivity of 556 kg lint ha^{-1} (Anon., 2016).

Over the past two decades, biotechnology has offered a tremendous scope primarily in the form of creating novel transgenic plants to combat biotic and abiotic stresses. Important milestone that helped to solve cotton bollworm problem was release of Bt cotton in the country. In the present state of cotton production, Bt cotton not only offered resistance to bollworms, but helped to boost the productivity, income level of farmer, ecological gain by low pesticide consumption and low residual impacts on biological entities including human being. Now a days, more than 95 per cent of area under conventional Indian cotton varieties has been replaced by Bt hybrids. Cultivation of Bt cotton has now become highly capital intensive, because of high nutrient demand and are more prone to sucking pests than conventional varieties.

Low yields of cotton in the country are mainly due to non adoption of improved production technologies, late sowing, imbalanced fertilizer and irrigation water management. Nutrients and water play a major role in increasing the productivity of Bt cotton. However, the rising prices for fertilizers and other inputs are of increasing concern for farmers as fertilizer and water management has an important impact on the profitability of cotton production.

The Bt hybrids bear more fruiting points and larger bolls which necessitates more nutrition. As the nutritional demands at various stages of growth of Bt cotton can ultimately decide the kapas yield, so a careful scheduling, quantity of fertilizers and method of application is needed. Water is the most important factor for cotton production. Inadequacy and uncertainty of rainfall often cause partial or complete failure of Bt cotton. When water become scarce, demand management becomes key to the overall strategy for managing water (Molden *et al.,* 2000). Over watering to cotton wastes valuable and scarce resources which lead to nutrient leaching and contamination of groundwater. Besides, under watering can decrease yields, optimum irrigation regime for cotton is essential (Detar, 2008).

Drip irrigation is an efficient method of water application which results in increased yield of crops including Bt cotton. Presently cotton is being irrigated with surface furrow method of irrigation where in the water use efficiency (WUE) is too low. In view of it, drip irrigation and fertigation to Bt Cotton plays a crucial role in increasing the cotton productivity and WUE. In India, total area under micro-irrigation system (Drip and Sprinkler) is 77,28,812 ha. Out of which drip irrigation occupied 33,71,597 ha and remaining area under sprinkler method of irrigation. Micro-irrigation system in Karnataka is 8,46,907 ha, where drip irrigation constitute 4,29,903 ha (Anon., 2016a).

Fertigation is an efficient method of applying fertilizers where irrigation water is utilized as the carrier and distributor of plant nutrients thus ensuring accurate and uniform application of nutrients in the vicinity of active root zone. However, fertigation with liquid fertilizer or 100 per cent water soluble fertilizer has been found to increase the efficiency in the application of fertilizer besides reducing the quantity of fertilizers applied. This in turn, reduces the cost of production and also minimizes the ground water pollution thereby preventing ecological disturbances and health risks occurred due to leaching and accumulation of nitrates in the deeper layers. As such, use of fertigation could prove as a blessing for Indian farming and pave the way for efficient use of costly and scarce fertilizers. Fertigation, where fertilizer is applied through an efficient (drip) irrigation system, nutrient use efficiency (NUE) could reach as high as 90 per cent besides achieving more than 95 per cent application efficiency. Therefore, the amount of fertilizer lost through leaching could be as low as 10 per cent in drip fertigation as compared to 50 per cent in traditional method of irrigation with conventional fertilizers.

It was noticed that the Bt cotton responds well to the varied agronomic practices, among them water and nutrient management are the most important ones. The present investigation focuses on the development of the most productive and profitable irrigation and nutrient management practices for irrigated Bt cotton and their effects on *Cry* protein expression. Variations in the efficacy of Bt cotton and the involved mechanisms need to be understood fully, so as to plan rational resistance management strategies to retard the rate of the development of resistance and to control target pests effectively by enhancing endotoxin expression through agronomic management. Studies made across the world revealed that stress conditions in Bt cotton are known to reduce their *Cry* protein status. This information helps to understand the effect of different moisture regimes on the *Cry* protein levels and to pest's reactions. For this reason, some well validated bioassay techniques (Greenplate, 1999) and enzyme-linked immunosorbent assays (ELISA) (Holt *et al.*, 2002) have been established to quantify changes in the concentration of Bt toxin proteins.

In the present context, there is a need to study the influence of fertigation involving the source, dosage and split application of fertilizers on seed cotton yield, nutrient uptake and nutrient use efficiency and their effects on *Cry* protein expression. In view of it, a field experiment was conducted at Agricultural Research Station, Dharwad farm, University of Agricultural Sciences, Dharwad, during *kharif* 2016-17 with the following objectives.

1. To assess the efficacy of water soluble fertilizers in Bt cotton applied through fertigation *vis-à-vis* conventional fertilizers.

2. To assess the effect of water soluble fertilizers under fertigation on growth and yield of Bt cotton.

3. To assess the effect of water soluble fertilizers under fertigation on fibre quality parameters and cry protein expression.

2. REVIEW OF LITERATURE

In the present investigation, an attempt was made to evaluate efficacy of water soluble fertilizers through drip, split application and to study its effects on growth, yield, fibre quality and *cry* protein concentration at various growth stages of intra *hirsutum* Bt cotton which was compared with conventional fertilizers has been reviewed in this chapter.

2.1 Drip irrigation

2.1.1 Effect of drip irrigation on growth and yield of cotton

Experiment conducted at Coimbatore revealed that drip irrigation favoured the growth of summer cotton and resulted in increased seed cotton yield by 34.5 per cent as compared to conventional (flood irrigation) method (Anon., 2005). Experiment at Punjab revealed 32 per cent higher seed cotton yield than check basin method of irrigation when same quantity of irrigation water and nitrogen was applied through drip irrigation system. Paired row sowing (PS) method of planting helped to increase seed cotton yield by 20 per cent along with saving of 50 per cent of water and cost of laterals. The water use efficiency (WUE) increased by 26 per cent (22.1 from 17.6 kg ha^{-1} cm^{-1}) in drip irrigation system when same quantity of water and nitrogen fertilizer was applied as compared with check basin. WUE was higher in PS as compared with normal sowing (Aujla *et al.*, 2004). Harmit *et al.* (2012) from Punjab reported that paired rows required only 50 per cent irrigation water under a drip irrigation system to produce higher seed cotton yield than normal sowing under check basin irrigation and equivalent to normal sowing under drip irrigation. Trials conducted at Mahatma Phule Agricultural University, Rahuri and showed that drip resulted into 24.7 per cent increase in seed cotton yield with 56.9 per cent water saving compared to that of surface irrigation (Pawar *et al*., 2014)

Lomte and Kagde (2009) at Parbhani reported that higher seed cotton yield under drip irrigation to the tune of 39 per cent over ridge and furrow irrigation and mean consumptive use of water and WUE in drip irrigation was more as compared to ridge and furrow irrigation. Drip irrigation had substantially increased the seed cotton yield as compared to furrow irrigation. Drip fertigation and drip band application of nitrogen increased the seed cotton yield compared to furrow band application (Veeraputhiran and Chinnusamy, 2009). Seed cotton yield was significantly higher due to application of irrigation through drip system over surface method of irrigation (Bharambe *et al*., 2002).

Singh *et al.* (2010) at Rajasthan reported that drip irrigation at 1.0 Etc saved 26.9 per cent water and produced 43.1 per cent higher seed cotton yield over conventional furrow irrigation (1.0 Etc). Imposing irrigation deficit of 0.8 Etc caused significant reduction in seed cotton yield to the tune of 9.3 per cent. Further increase in deficit irrigation from 0.7 Etc to 0.5 Etc significantly decreased seed cotton yield over its subsequent higher irrigation level.

Studies carried out at Dharwad showed that crop performance was better under drip compared to furrow method of irrigation. The highest (1,340 kg ha^{-1}) and lowest (1,100 kg ha^{-1}) seed cotton yield were recorded in case of drip irrigation at 1.2 evapotranspiration in single row method and furrow irrigation and at 1.0 evapotranspiration in paired row method of sowing respectively (Manjunatha *et al*., 2010). Study at Akola revealed that scheduling of irrigation at 1.0 Etc and application of 125 per cent RDF through drip, recorded highest seed cotton yield (2,170 kg ha^{-1}) which was at par with 0.8 Etc with 125 per cent RDF. The yield enhancement due to drip system was 10.53, 11.49 and 12.39 per cent at 0.6, 0.8 and 1.0 Etc respectively as compared to application of irrigation at 0.6 IW/CPE ratio (Bhalerao *et al*., 2011).

Study conducted at Punjab depicted that drip irrigation under normal sowing resulted higher seed cotton yield (4,530 kg ha^{-1}) than check basin (2,580 kg ha^{-1}) and water use efficiency (WUE) under drip irrigation increased from 1.65 to 1.85 and 0.99 to 1.65 kg ha^{-1} mm^{-1} during first and second year respectively, when same quantity of water and nitrogen was applied. Studies also revealed that higher seed cotton yield (SCY), WUE and agronomic efficiency of nitrogen (AEN) in paired row planting under drip irrigation than normal sowing and also saved 25 per cent irrigation water as well as cost of laterals (Thind *et al.,* 2008).

Trial conducted at Raichur depicted that seed cotton yield (SCY) of Bt cotton was significantly higher in treatment receiving irrigation at 0.8 IW/CPE with 150 per cent RDF (3,184 kg ha^{-1}) over other treatment combinations of lower irrigation and fertilizer levels. The SCY obtained with optimum level of irrigation at 0.8 IW/CPE and 0.6 IW/CPE level with 150 per cent RDF were on par (3,184 and 3,152 kg ha^{-1} respectively) with each other. Yield under unirrigated condition (2,484 kg ha^{-1}) was on par with irrigation at 0.2 IW/CPE level (2,624 kg ha^{-1}). There was about 21 per cent improvement in seed cotton yield in high irrigation frequency (0.8 IW/CPE) over unirrigated condition (Ghongane *et al.*, 2009). On farm trial conducted at Nagpur by Ramamurthy *et al.* (2009) concluded that drip irrigation at 0.6 Etc recorded significantly higher seed cotton yield in all the 3 years (2.24, 2.32 and 2.18 t ha^{-1}, respectively) as compared to other treatments but it was on par with 0.8 Etc and 1.0 Etc. Lowest seed cotton yield was recorded in farmer's practice of flood irrigation.

Ramesh *et al.* (2006) at Madurai reported that drip irrigation at 100 per cent PE once in 3 days interval with coir pith mulching was found to be a viable method for higher productivity and profitability in summer cotton under sufficient water availability. However, drip irrigation at 80 per cent PE once in 3 days interval with coir pith mulching has been found viable for summer cotton in a water scarcity situation.

Studies on drip irrigation water requirement of *hirsutum* hybrid cotton at Bagalkot indicated that drip irrigation at 40 per cent CPE throughout the crop growth period resulted in 10 per cent higher seed cotton yield and 2.66 times higher water use efficiency over surface irrigation at 0.8 IW/CPE (Patil *et al.*, 2004). Further, studies undertaken at Arabhavi for three years on *hirsutum* hybrid cotton for water requirement shown that drip irrigation at 50 per cent potential evaporation (PE) throughout crop growth period or 50 per cent PE up to 45 DAS + 75 per cent PE thereafter registered significantly higher yield and higher water use efficiency over other treatments (Patil *et al.*, 2004a)

2.1.2 Economics of drip irrigation

The highest net income was realized with 100 per cent drip irrigation (` 48,161 $ha^{-1}$ in winter and ` 32,366 ha^{-1} in summer) compared to furrow irrigation, the benefit cost ratio was lower in drip irrigation mainly due to higher initial investment compared to furrow method of irrigation (Veeraputhiran and Chinnusamy, 2005). The benefit cost ratio were 5.15 and 2.96, respectively for the drip and furrow method of irrigation (Jadhav *et al.*, 1990).

2.2 Response of Bt cotton hybrids to major nutrients

2.2.1 Effect of nutrient levels on growth and yield of Bt cotton

Field experiment conducted at ARS, Dharwad showed that SPAD readings were significantly higher with application of 120 kg N ha^{-1} (38.1) when compared with 80 kg N ha^{-1} (36.3) at 120 DAS. Similar trend was followed at 150 DAS (Hallikeri *et al.*, 2011). Satyanarayana and Janawade (2006) at Dharwad reported that application of 100 per cent RDF produced significantly higher yield components like number of harvested bolls $plant^{-1}$, boll weight, 100 seed weight and cotton yield $plant^{-1}$ which resulted in increased seed cotton yield (1,549 kg ha^{-1}) over 50 per cent (1,258 kg ha^{-1}) and 75 per cent RDF (1,428 kg ha^{-1}) respectively. Studies carried out at Coimbatore depicted that higher nutrient levels (150:80:80 kg ha^{-1}) induced significantly higher dry matter production (4,624 kg ha^{-1}), number of bolls per plant (34.06), boll weight (5.41 g) and seed cotton yield (2,411 kg ha^{-1}) compared to 120:60:60 kg NPK ha^{-1} (2,164 kg ha^{-1}) (Rajendran *et al.*, 2011).

Basavanneppa (2012) at Agricultural Research Station, Siruguppa observed that application of 200:100:100 NPK kg ha^{-1} recorded higher plant height, monopodia and sympodia per plant and it was at par with application of 160:80:80 NPK kg ha^{-1}. Corresponding higher seed cotton yield (2,515 kg ha^{-1}), yield per plant (135.8 g) and boll weight (5.09 g) were recorded in application of 180:90:90 kg NPK ha^{-1}. At Raichur, the newly released ‘RAMPBS 155’ upland cotton variety recorded the maximum yield (3,003 kg ha^{-1}) with fertilizer levels 200:100:100 NPK kg ha^{-1} (Manjappa *et al.*, 1997). Bastia (2000) reported increased seed cotton yield with increased fertilizer rates from 80:40:40 kg ha^{-1} NPK (1,085 kg ha^{-1}) to 140:70:70 kg ha^{-1} NPK (2,064 kg ha^{-1}) which was on par with the application of 120:60:60 NPK kg ha^{-1}.

2.2.2 Effect of dosage of fertilizers

Rajendran *et al.* (2011) at Tamil Nadu reported that soil application of 150 per cent RDF combined with micro nutrient mixture favorably increased the growth characters, yield attributes and recorded 26 per cent higher seed cotton yield as compared to 100 per cent RDF. Experiment conducted at Agricultural Research Station, Dharwad indicated that higher seed cotton yield (2,836 kg ha^{-1}) was obtained in drip irrigation at 0.8 Etc with 125 per cent RDF which was on par with the drip irrigation at 1.0 Etc (2,791 kg ha^{-1}) as compared to drip at 0.6 Etc (2,536 kg ha^{-1}) (Aladakatti *et al.*, 2012). Significantly higher seed cotton and stalk yields, growth and yield attributes were obtained with the application of N: P_2O_5: K_2O at 240:50:120 kg ha^{-1} (Modhavadia *et al.*, 2012). Nehra and Yadav (2012) reported that among fertility levels, application of 125 per cent of RDF produced significantly higher seed cotton yield (2,121 kg ha^{-1}) over 100 per cent RDF (80:40:20 kg ha^{-1}) in intra *hirsutum* hybrid cotton.

At Bathinda, the highest seed cotton yield was recorded with a nitrogen level of 150 kg ha^{-1} which was at par with 175 kg N ha^{-1} but significantly higher than 200 kg N ha^{-1} (Buttar *et al.*, 2010). Raghu and Dileep (2010) noticed application of N upto 150 kg ha^{-1} increased yield in Bt cotton hybrid (2,928 kg ha^{-1}) and further increase in N levels decreased the yield. Application of 60 kg P_2O_5 and K_2O ha^{-1} recorded significantly higher seed cotton yield over 30 kg ha^{-1}. Increasing trend in plant height, sympodial branches $plant^{-1}$, seed cotton yield $plant^{-1}$, number of bolls $plant^{-1}$ was observed at Akola with increased fertilizer levels but difference between 150 per cent RDF and 125 per cent RDF was not significant. Both the results were significantly superior to 100 per cent RDF but ginning percentage did not get influenced significantly with various NPK levels (Bhalerao *et al.*, 2012). Studies at Coimbatore indicated that 150 per cent RDF as drip fertigation combined with biofertigation of liquid formulation of azophosmet @ 250 ml ha^{-1} has recorded the highest seed cotton yield of 3,395 kg ha^{-1} and was significantly superior to control (Jayakumar *et al.*, 2015).

Ravikiran and Halepyati (2013) at Raichur resulted that application of 125 per cent RDF in combination with 0.5 per cent trace micronutrient recorded the highest seed cotton yield, lint index, uptake of nitrogen and phosphorus (19.88 q ha^{-1}, 96.99 g $plant^{-1}$, 5.20 and 32.34 kg ha^{-1} respectively), whereas in absence of foliar nutrition with 100 per cent RDF recorded the lowest seed cotton yield, lint index, uptake of nitrogen and phosphorus (12.12 q ha^{-1}, 59.09 g $plant^{-1}$, 4.69, 88.13 and 18.51 kg ha^{-1} respectively). Experimental trials at Indore revealed that among various levels of fertilizer application (40:20:10, 60:30:15 and 80: 40: 20 kg NPK ha^{-1}), the fertilizer level (80:40:20 kg NPK ha^{-1}) recorded significantly higher seed cotton yield (948 kg ha^{-1}), lint yield (314 kg ha^{-1}) and seed index (8.45 g) (Tomar *et al.*, 2000).

Trials at Dharwad indicated that application of 150 per cent RDF (45:22.5:22.5 NPK kg ha^{-1}) recorded significantly higher seed cotton yield (4,990 kg ha^{-1}), which was 12.8 per cent higher than RDF (4,020 kg ha^{-1}) (Kubsad *et al.,* 2004). Rambhav and Wankhade (2005) observed that increase in seed cotton yield by 10.55 per cent with the increase in fertilizer levels from 25: 12.5: 12.5 to 50: 25: 25 kg NPK per ha and the yield was marginally increased only by 1.76 per cent with the increase in fertilizer level from 50: 25: 25 kg NPK per ha to 75: 37.5: 37.5 kg NPK per ha. Narayana *et al.* (2008) at Guntur, studied the effect of different levels of fertilizer (120: 60: 60, 150: 100: 100, 180: 140: 140 kg NPK ha^{-1}) with varied spacing and concluded that the recommended level of 120: 60: 60 kg NPK per ha was sufficient for achieving the higher seed cotton yield (3,921 kg ha^{-1}). Trials carried out at Hissar and Sirsa indicated seed cotton yield of 3,061 kg ha^{-1} and 3,902 kg ha^{-1} respectively, with a fertilizer dose of 125 per cent RDF (187.5:75:75 NPK ha^{-1}) as compared to 75 and 100 per cent RDF at both the locations (Devraj *et al.*, 2011). Under vertisol, highest seed cotton was recorded with fertility level of 200:100:100 kg NPK ha^{-1} (2,864 kg ha^{-1}) and was at par with the fertility level of 175:87.5:87.5 kg NPK ha^{-1} (2,754 kg ha^{-1}) at Parabani (Asewar *et al.*, 2013).

2.2.3 Effect on nutrient uptake and use efficiency

Experiment conducted at Nagpur revealed that the fertilizer use efficiency was significantly influenced by variable rate of fertilizer application. The highest response was at sub optimal fertilizer dose with decline in yield response with every addition of 25 per cent fertilizers, which followed law of diminishing returns but significance was found up to 150 per cent RDF. It was clearly indicated that adjusting 2 to 3 split application of fertilizer as per soil moisture is not enough, fine tuning of other agronomic practices such as soil moisture conservation and drainage are equally important for realizing better fertilizer use efficiency (FUE) (Ambati and Soniya, 2012). Bhalerao *et al*., (2012) at Akola observed that significant response to uptake of N, P and K with increased NPK levels from recommended dose of fertilizer of fertilizers (RDF) to 150 per cent RDF. Increase in the uptake of nutrients was because of increasing trend in the biological yield with increasing fertilizer levels beyond RDF.

Mussaddak (2004) in Syria reported that the nitrogen uptake was significantly increased under drip fertigation method compared with surface irrigation coupled with soil application of fertilizers. Nitrogen uptake was 28 g for the surface irrigated treatment and 47.5 g for the drip fertigated treatment. Based on this, it was concluded that under drip fertigation more nitrogen fertilizer was taken up and utilized for the production of seed cotton yield. Studies at Bengaluru indicated that total nitrogen uptake at harvest was significantly higher in treatment which received 100 per cent RDF with fertigation in 5 splits (161.00 kg ha^{-1}) over RDF with soil application and other fertigation treatments. Uptake of NPK in fertigation treatments was significantly superior over the soil application of fertilizer which led to increase the dry matter production in different plant parts at harvest in intraspecific cotton (Bharathraj *et al.,* 2015).

Bhati and Singh (2015) at Punjab found that nutrient use efficiency of nitrogen and phosphorus was not affected significantly by N and NK split application, but K use efficiency was found to be significantly higher in N split application (5.43 kg ha^{-1}) as compared to NK split application treatment. Nutrient use efficiency of P and K did not influence by timing of fertilizer application, whereas N use efficiency was significantly higher (6.97 kg ha^{-1}) when the fertilizer was applied at sowing, 30 and 45 DAS. Nitrogen uptake was highest when the fertilizer was applied in 4 equal doses at sowing, 30, 45 and 75 DAS and was at par with 4 equal doses at sowing, 30, 45 and 60 DAS. Phosphorus and K uptake was highest when the fertilizer was applied in 4 equal doses at sowing, 30, 45 and 60 DAS. Drip irrigation and fertigation has much scope in increasing the productivity of water and yield per unit area. Uptake of N, P and K was found maximum with irrigation applied at 1.0 Etc along with 125 per cent RDF (125:62.5:62.5 kg NPK ha^{-1}) at Akola (Bhalerao *et al.*, 2011). Veeraputhiran and Chinnusamy (2005) also reported that drip fertigation substantially increased the NUE compared to furrow irrigation with band application. Results at UAS, Raichur indicated that application of 125 per cent RDF produced significantly higher uptake of nitrogen

(107.81 kg ha^{-1}), phosphorus (30.08 kg ha^{-1}) and potassium (109.25 kg ha^{-1}) over application of 100 per cent RDF (98.38 kg ha^{-1}, 23.39 kg ha^{-1}and 100.67 q ha^{-1}, respectively) (Hosamani *et al.*, 2013).

Nalayani *et al.* (2010) at Coimbatore reported that the plot which received 100 per cent recommended dose of fertilizer of N and P (RDNP) recorded significantly higher nitrogen (98.4 kg ha^{-1}) and phosphorus uptake (18.4 kg ha^{-1}) and was on par with application of 75 per cent RDNP (92.6 and 17.2 kg ha^{-1}, respectively). Significantly lower uptake was recorded in 50 per cent RDNP and absolute control.

Higher uptake of nitrogen, phosphorus and potassium by cotton was recorded with 100 per cent RDF (41.6, 9.2 and 34.9 kg ha^{-1}, respectively) as compared to 50 per cent RDF application (33.4, 8.3 and 30.4 kg ha^{-1}, respectively) (Katkar *et al.*, 2002). At Dharwad, Krishnegowda (2004) reported increased nutrient uptake with increase in levels of fertilizer from 100 per cent (198.17, 35.95 and 307.91 kg N, P and K ha^{-1}, respectively) to 150 per cent RDF application (223.86, 49.20 and 363.79 kg N, P and K ha^{-1}, respectively). Trials at UAS, Dharwad indicated that nitrogen, phosphorus and potassium uptake by Bt cotton significantly increased with increase in nutrients levels from 100 per cent to 175 per cent RDF. The uptake of Nitrogen (93.18 kg ha^{-1}), phosphorus (14.02 kg ha^{-1}) and potassium (82.66 kg ha^{-1}) were higher with the application of 175 per cent RDF (Gundulur *et al.*, 2013).

2.2.4 Economics

Among fertilizer levels, 100 per cent RDF resulted in significantly higher net returns (` 20,270 ha$^{-1}$) which were 29.2 and 9.7 per cent higher over 50 and 75 per cent RDF (Satyanarayana and Janawade, 2006). Highest gross return (` 62,649 ha^{-1}), net returns (` 39,568 ha^{-1}) and B:C (2.73) were recorded in the treatment with 4 splits of nutrients at 10, 30, 45 and 60 days after sowing (DAS) which was on par with 3 splits of 10, 30 and 45 DAS. Both proved significantly superior over rest of split application of nutrients (Gokhale *et al.*, 2012).

2.2.5 Effect of drip fertigation on nutrient uptake and use efficiency

The availability of N, P and K was significantly influenced by the soluble fertilizers. The water soluble fertilizers (WSF), resuled into 61.66 per cent higher seed cotton yield than conventional method of irrigation and fertilizer application. Similarly, seed cotton yield was higher in WSF than conventional fertilizers (CF) (17.77 per cent) with paired row planting of Bt cotton (0.75 - 1.5 x 0.75 m) at Maharashtra (Bhakare *et al.,* 2015).

Solaimalai *et al.* (2005) reported nutrient use efficiency under fertigation which was 90 per cent as compared to 25 to 35 per cent in conventional methods. The quantity of fertilizer lost through leaching was as low as 10 per cent in fertigation where as it was 50 per cent in traditional system. Higher plant height, leaf area, number of bolls per plant, monopodial and sympodial branches were recorded in the paired row planting with 125 per cent recommended dose of fertilizer of water soluble fertilizers. The mobility of nutrients was comparatively higher due to the use of water soluble fertilizers (WSF) as compared to conventional fertilizers (CF) (Bhakare *et al.*, 2015).

Rajendran and Arunvenkatesh (2014) at Coimbatore found that ammonical nitrogen concentration increased with the increased level of fertilizer doses *viz.,* 28 to 210 mg kg^{-1} soil. Concentration of ammonical nitrogen was higher in drip fertigation with water soluble fertilizers at all levels when compared to drip fertigation with straight fertilizers and surface irrigation with soil application of fertilizers. The nitrate nitrogen concentration increased with the increased levels of fertilizer doses *viz.*, 28 to 168 mg kg^{-1} soil. Nitrate nitrogen concentration was higher in drip fertigation with water soluble fertilizers at all levels when compared to drip fertigation with straight fertilizers and surface irrigation with soil application of fertilizers.

2.3 Effect of Liquid fertilizers

2.3.1 Effect of liquid fertilizers through drip fertigation

Field experiments carried out over two years at Agricultural College and Research Institute, Coimbatore showed highest plant height, more leaf area index (LAI), dry matter production (DMP) and higher seed cotton yield of 3676 and 3521 kg ha^{-1} during 2011-12 and 2012-13, respectively, under drip fertigation with 100 per cent recommended dose of fertilizer of NPK using soluble fertilizers (urea phosphate and MOP) and foliar spray of 1 per cent urea phosphate. This was followed by drip irrigation at 100 per cent recommended dose of fertilizer of NPK and foliar spray of 1 per cent urea phosphate which was also significantly increased the cotton growth in terms of plant height, LAI, DMP and seed cotton yield (2443 and 2364 kg ha^{-1} during 2011-12 and 2012-13, respectively) over surface irrigation with soil application of fertilizers (Ayyadurai and Manickasundaram, 2014).

Baskar and Jagannathan (2014) at Tamil Nadu Agricultural University, Coimbatore reported that wider crop geometry 150 x 90 cm with fertigation of 125 per cent water soluble fertilizers recorded higher dry matter partitioning into different plant parts and yield attributes $plant^{-1}$. However, higher seed cotton yield of 3066 kg ha^{-1} and 3286 kg ha^{-1} during 2012-13 and 2013-14 respectively were recorded with crop geometry of 120 x 90 cm and 125 per cent as water soluble fertilizers. Lower dry matter partitioning, yield attributes and yield were recorded with conventional irrigation and fertilizer application.

Bhakare *et al.* (2015) at MPKV, Rahuri reported higher plant height, leaf area, number of bolls per plant, monopodial and sympodial branches in paired row planting with 125 per cent recommended dose of fertilizer of water soluble fertilizers (WSF). They found that higher seed cotton yield and cotton seed yield *i.e.* 52.33 and 32.65 q ha^{-1} were recorded in WSF which was 17.77 and 16.53 per cent, respectively higher than conventional fertilizers (CF). Application of 75 per cent RDF through water soluble fertilizer produced more seed cotton yield (44.17 q ha^{-1}) than surface irrigation with 100 per cent RDF through conventional fertilizers (32.37 q ha^{-1}) and concluded that 25 per cent of fertilizer saving could be achieved with paired row planting of Bt cotton (0.75 - 1.5 x 0.75 m) with the application of water soluble fertilizer through drip irrigation.

A field experiment carried out at Cotton Breeding Station (CBS), TNAU, Coimbatore during winter irrigated season of 2009 showed that drip fertigation with 75 per cent RDF as water soluble fertilizers had significant influence on the growth and yield attributes *viz*., higher sympodial branches per plant, number of bolls per plant and boll with increased uptake of major nutrients higher over other treatments, which registered the highest seed cotton yield of 3,324 kg ha^{-1} and was closely followed by drip fertigation with 100 per cent recommended dose of fertilizer of NPK as straight and water soluble fertilizers *viz*., 3,063 and 3,062 kg ha^{-1} respectively (Rajendran and Arunvenkatesh, 2014).

Jayakumar *et al.* (2015) at Coimbatore reported that drip fertigation with 150 per cent RDF and biofertigation of azophosmet registered higher plant height of 113 cm, total dry matter production (DMP) of 6,875 kg ha^{-1}, leaf area index (LAI) of 4.36, sympodial branches (18.08), fruiting points (68.5), bolls (29.5) and boll weight (4.8 g $boll^{-1}$) as compared to other treatments. It was on par with fertigation of 150 per cent RDF with plant height (112.9 cm), total DMP (6,866.4 kg ha^{-1}), LAI (4.33), sympodial branches (17.8), fruiting points (67.5), bolls (29) and boll weight (4.9 g $boll^{-1}$) and fertigation with 125 RDF with biofertigation respectively.

2.3.2 Economics of soluble fertilizer applied through drip fertigation

Pawar *et al.* (2014) studied the economic analysis of drip irrigation and fertigation and revealed that the cost of cultivation under drip with band application of fertilizers and drip fertigation was higher than conventional band application. However, the highest net income (` 1,31,381.2 $ha^{-1}$), total net income (` 3,07,273.4 ha^{-1}) and net extra income over conventional method (` 61,030.6 ha^{-1}) were realized in 125 per cent fertigation, but it was on par with the economical parameters obtained in 100 and 75 per cent fertigation. The benefit cost ratio was lowest in drip fertigation and drip band application mainly due to higher initial investment for drip irrigation and high cost of water soluble fertilizers.

2.3.3 Nutrient uptake by Bt cotton as influenced by fertigation of soluble fertilizers

Bhakare *et al.* (2015) at MPKV, Rahuri indicated that the mobility of nutrients was comparatively higher due to the use of water soluble fertilizers (WSF) as compared to conventional fertilizers (CF). The available N and K moved in soil, 30 cm laterally and vertically while available P moved upto 15 cm in those directions from the emitter. The availability of N, P and K was significantly influenced by the treatments, indicating increase in availability of nutrients due to water soluble fertilizers, resulting into 61.66 and 55.18 per cent higher seed cotton and cotton seed yield, respectively than conventional method of irrigation and fertilizer application.

2.4 Effect of split application of nitrogen and potassium

2.4.1 Effect of split application of N and K on growth and yield of Bt cotton

At Agricultural Research Station, Dharwad it was concluded that drip irrigation at 0.8 Etc with 125 per cent RDF (150:75:75 NPK kg ha^{-1}), through fertigation of N and K in six splits at an interval of 15 days to Bt cotton was found optimum for realizing higher seed cotton yield in medium black soil (Aladakatti *et al.,* 2012). Experiment conducted at UAS, Bengaluru concluded to adopt 5 splits application of all the major nutrients under surface fertigation to achieve higher cotton productivity and increasing benefit cost ratio (Bharathraj *et al.*, 2015). Time of application of nutrients had pronounced effect on seed cotton yield. Four split application of nutrients at 10, 30, 45 and 60 DAS (2,049 kg ha^{-1}) and three split application of nutrients at 10, 30 and 45 DAS (2,308 kg ha^{-1}) were at par and recorded significantly higher seed cotton yield compared to rest of the splits and at different timings (Gokhale *et al.*, 2012). Recommended practice with 100 per cent P and K + 33 per cent N as basal and remaining N in two equal splits at 45 and 60 DAS was on par with skipping basal dose of NPK and supply of all dose as top dressing in two equal splits at 45 and 60 days after sowing produced highest cotton yield as compared to other treatments (Mariyappan *et al.*, 2004).

Studies at Rahuri indicated that application of N in six splits (20 per cent at sowing as basal and remaining in 5 equal splits at 30, 45, 60, 75 and 90 DAS) recorded significantly higher plant height (114 cm), sympodial branches (15.6 $plant^{-1}$), drymatter (200 g $plant^{-1}$), bolls (37.1 $plant^{-1}$), seed cotton yield per plant (160.6 g $plant^{-1}$) and seed cotton yield per hectare (3.01 t ha^{-1}) (Giri *et al.*, 2014). Bhati and Singh (2015) at Abohar (Punjab) reported that split application of N and K_2O did not have any significant effect on seed cotton yield, yield $plant^{-1}$, bolls $plant^{-1}$, boll weight and seed index. Application of recommended dose of fertilizer of fertilizers by skipping basal and applying the same in two splits at 45 and 60 DAS registered highest number of sympodial branches plant^{-1}, boll weight, bolls plant^{-1} and yield ha^{-1} as compared to recommend practices and other type of split applications (Srinivasan, 2003). Drip fertigation with RD of N (150 kg ha^{-1}) and K (20 kg ha^{-1}) in six equal splits at an interval of 15 days gave significantly highest seed cotton yield and maximum WUE (3.44 kg ha^{-1} mm^{-1}) was recorded with drip irrigation at 0.8 Etc (Yadav *et al.*, 2014). Results at Agricultural Research Station, Dharwad indicated that split application of fertilizers through drip with 90 per cent RDF in 19 equal splits at five days intervals from 30 to 120 DAS and 10 per cent RDF as basal application to intra *hirsutum* hybrid cotton produced consistently higher yield as compared to conventional method of fertilizer application (Patil *et al.*, 2000). Trial carried at Adilabad indicated that split application of N at different times was not significant. The split aplication of N at 25, 55, 85 and 115 DAS of the crop was the best schedule to maximize the production of sympodial branches plant^{-1} and number of bolls plant^{-1} (Das *et al.*, 2009).

2.4.2 Effect of major nutrients on quality parameters of Bt cotton

Trials at Brazil on fibre quality parameters (fibre percentage, length, uniformity, short fibre index, resistance, elongation at rupture, micronaire index, maturity, degree of yellowing, reflectance degree and count strength product (CSP index) of two cotton cultivars (BRS Aroeira and BRS Araripe) in combination with treatments of irrigation depths (260.9, 418.9, 514.2, 711.8 and 894.6 mm) revealed that best fibre quality was found with irrigation depths of 514.2 and 418.9 mm for the upland cotton cultivars BRS Araripe and BRS Aroeira, respectively (Francisco *et al.*, 2015). There was no significant difference in fibre length, fineness, uniformity index and elongation in both 100 per cent and 75 per cent irrigation levels (Basal *et al.*, 2009). Studies carried out at Dharwad revealed that influence of potassium on fibre length, uniformity ratio, micronaire value was found non significant but fibre tenacity was influenced significantly. Higher fibre tenacity of 23.4 g tex^{-1} was recorded with RDF + K foliar sprays each at early (90 DAS) and peak boll formation stage (110 DAS) as compared to the treatment without potassium (22.2 g tex^{-1}) during second year (Aladakatti *et al.*, 2011).

Dewdar (2013) evaluated soil and foliar application of potassium. They indicated that soil application with addition to foliar spray of K_2SO_4 at 2 per cent each at early boll formation (EBF) and peak boll formation (PBF) stage showed higher number of leaves, total leaf area, dry weight of leaf, cotton seed yield, number of bolls, boll weight, lint percentage, seed index, lint index, fibre length and fibre strength. Experiment conducted at Raichur revealed that fibre quality parameters such as mean fibre length, ginning percentage, lint index were not significantly influenced by spacing levels, fertilizer levels and NAA sprays (Vishwanath *et al*., 2010).

Trials at Parbhani depicted that maximum span length in the plot receiving 100 per cent N and P fertilizer while maximum tenacity and elongation percentage were recorded in the plot receiving 75 per cent N and P fertilizers (Dhale *et al.*, 2011). Lint yield was increased up to 40 per cent by soil applied potassium under irrigated conditions as compared to non irrigated conditions. They reported that lint yield was not much higher with foliar applied potassium where already soil potassium applications were made according to university of Arkansas recommendations (Coker *et al*., 2009).

Narayan *et al.* (2008) at Guntur, revealed that application of 180: 140: 140 kg NPK ha^{-1} to soil registered significantly higher ginning percentage (33.2 per cent), fibre length (30.28 mm) and lower micronaire (4.32) compared to lower levels of fertilizer. However, lint index and fibre elongation recorded non significant difference to fertilizer levels. Ambati and Sonia (2012) observed ginning percentage, 2.5 per cent span length, uniformity ratio and bundle strength did not differ significantly to fertilizer levels. Whereas, application of 150 per cent RDF recorded significantly lower micronaire (3.07) compared to 125 and 100 per cent RDF (31.9 and 3.21, respectively). Thimaareddy *et al.* (2013) reported that application of 150 per cent RDF imparted significantly higher ginning percentage (35.2 per cent), lint index (5.6) and fibre length (32.82 mm) over 100 per cent RDF (32.77per cent, 4.05, 31.68 mm, respectively). However, it was at par with 125 per cent RDF

2.5 *Cry* protein concentration in cotton

2.5.1 Effect of moisture regime on *Cry* protein expression

Experiment conducted at Agricultural Research Station, Dharwad revealed that 0.8 IW/CPE recorded significantly higher *Cry* protein concentration as compared to other regimes. Effect of moisture regimes on pest incidence was little and not significant at early stages (60 and 90 DAS). However, pest incidence was significantly affected with moisture regimes at 120 DAS, owing to the decreased level of *Cry* protein due to increased effect of soil moisture (Hallikeri *et al.*, 2009).

2.5.2 *Cry* protein expression as influenced by major nutrients

At Agricultural Research Station, Siruguppa noticed that the Bt hybrid JK Durga exhibited highest delta endotoxin concentration (2.33 µg g^{-1}) at 45 DAS as compared to other 3 genotypes than at 135 DAS (1.58 µg g^{-1}). Application of 200:100:100 N: P_2O_5:K_2O kg ha^{-1} recorded maximum delta endotoxin concentration (2.31 µg g^{-1}) at 45 DAS as compared to other nutrient levels (Basavanneppa *et al.*, 2015). Studies carried out at UAS, Dharwad found that supplementing green manure along with RDF recorded highest *Cry 1Ac* protein (1.95 µg g^{-1} of seeds) followed by FYM alone (1.75 µg g^{-1} of seeds), vermicompost + RDF (1.66 µg g^{-1} of seeds) and vermicompost alone (1.14 µg g^{-1} of seeds) (Hosmath *et al.*, 2004). Studies at UAS, Dharwad found that increase in fertilizer level increased the delta endotoxin concentration. Significantly higher delta endotoxin concentration was recorded with 217: 59: 148 NPK kg ha^{-1} (2.04 µg g^{-1}) at 75 DAS followed 181: 49:124 and 145: 39: 99 NPK kg ha^{-1} (Patil, 2007).

Manpreet and Dhawan (2014) at Punjab, reported maximum expression (19.24, 20.93 and 20.71 µg g^{-1} in leaves, squares and bolls, respectively) of *Cry 2Ab* at higher nitrogen dose @ 300 kg ha^{-1}, while it was minimum (18.67, 20.44 and 20.14 µg g^{-1} in leaves, squares and bolls, respectively) at low nitrogen dose @ 150 kg ha^{-1}. At Stoneville, MS, USA, Pettigrew and Adamczyk (2006) observed that plants applied with the highest nitrogen (168 kg N ha^{-1}) exhibited 14 per cent higher leaf *Cry 1Ac* concentration and a three per cent higher leaf chlorophyll concentration than plants which only received 112 kg N ha^{-1}. Studies at UAS, Raichur indicated that *Cry 1Ac* content in squares and boll rind marginally increased with increase in fertilizer levels from 50 to 150 per cent RDF and it declined with the advancement of the crop growth (Ghongane *et al.*, 2009). Higher *Cry* protein levels in squares and boll rind in the early stages (90 DAS) of crop growth which declined progressively and reached to a negligible amount at 165 DAS. Application of 150 per cent RDF recorded significantly higher *Cry* protein in all the growth stages compared to lower levels (Ranjithkumar *et al.,* 2011). Studies at Agricultural Research Station, Dharwad depicted that application of 150 per cent RDF (150: 75: 75kg NPK ha^{-1}) recorded signicantly higher *Cry 1Ac* and *Cry 2Ab* protein content in leaf over other nutrient levels at 60, 90 and 120 days after sowing (*Cry 1Ac* of 3.96, 4.47 and 2.16 µg g^{-1} fresh weight and *Cry 2Ab* of 42.06, 52.88, 23.93 µg g^{-1} fresh weight respectively) (Deepa and Aladakatti, 2015).

2.5.3 *Cry* protein expression as influenced by split application of nitrogen and potassium

Studies at UAS, Dharwad revealed that *Cry 1Ac* content was high *i.e.*, 5.51-7.85, 3.88-5.97 and 2.97-6.34 µg g^{-1} dry weight in leaves, squares and bolls, respectively at 80 DAS. Later on the expression declined throughout the season and reached minimum at 150 DAS (Manjunatha *et al.,* 2009). Studies at Dharwad depicted that N fertilization and split application of N fertilizer significantly improved the *Cry* protein level. At 60 days after sowing (DAS) increased level of nitrogen from 120 and 160 kg N ha^{-1} increased the *Cry* protein by 9.3 and 14.8 per cent over 80 kg N ha^{-1}. Application of N in 7 splits significantly improved the *Cry* protein level (5,043 ng g^{-1}) over either N applied in 4 splits (4,066 ng g^{-1}) or recommended practice of three splits (3,583 ng g^{-1}). Also indicated that increasing level of nitrogen from 80 to 120 and further to 160 kg ha^{-1} significantly increased seed cotton yield by 12 and 19 per cent, respectively (Hallikeri *et al.,* 2011).

Experiment conducted at Agricultural Research Station, Dharwad indicated that split application of N & K *i. e.* 25 per cent N and K_2O + 100 per cent P_2O_5 as basal and 25 per cent N & K_2O each at 30, 60 and 90 DAS recorded significantly higher *Cry* protein content at 60, 90 and 120 DAS (*Cry 1Ac* of 3.70, 4.38, 2.18 µg g^{-1} fresh weight and 42.34, 53.65 and 2 *Cry 2Ab* of 3.69 µg g^{-1} fresh weight, respectively) as compared to other split applications (Deepa *et al.,* 2015). Trials conducted at Main Agricultural Research Station (MARS), Dharwad concluded that the endotoxin content in the leaves of Bt cotton is dependent on the nitrogen levels and potassium nitrogen ratios. Application of 180 kg N ha^{-1} with K:N ratio of 1.0 (180:180 kg NK ha^{-1}) was found optimum for better expression of the endotoxin in the leaves of Bt Cotton (Manjunatha *et al*., 2015).

2.6 Studies on fertigation

2.6.1 Effect of fertigation on growth and yield of Bt cotton

Trials at Agricultural Research Station, Dharwad depicted that significantly higher seed cotton yield and water use efficiency (WUE) was obtained with fertigation of 125 per cent RDF (2,836 kg ha^{-1} and 4.76 kg ha^{-1} mm^{-1}) as compared to 100 per cent RDF through fertigation (2,641 kg ha^{-1}) and through soil application (2,668 kg ha^{-1}) (Aladakatti *et al*., 2012). Through fertigation 25 per cent fertilizer could be saved. Besides, as nutrients are supplied along with the water in the root zone through drip system, root proliferation was greater when the nutrients were applied to root zone resulting in enhanced uptake of nutrients and water (Balasubramanian *et al.*, 2000). Seed cotton yield (39.07 q ha^{-1}) obtained under 75 per cent RDF as water soluble fertilizers through fertigation was on par with treatment where 100 per cent RDF as conventional fertilizers applied through soil (34.59 q ha^{-1}) indicating 25 per cent fertilizer saving due to fertigation (Pawar *et al*., 2014).

Application of 75 per cent RDF through water soluble fertilizers could produce more yield than surface irrigation with 100 per cent RDF through conventional fertilizers. It was be concluded that 25 per cent of fertilizer saving could be achieved with paired row planting of Bt cotton (0.75 - 1.5 x 0.75 m) with the application of water soluble fertilizers through drip irrigation (Bhakare *et al.,* 2015). Under fertigated condition improved seed cotton yield, dry matter, earliness and in some cases lint properties were recorded. Under fertigated cotton, seed cotton yield increased by more than 50 per cent in some cases as compared with that of surface irrigation method (Mussaddak and George, 2001). Trials at Coimbatore revealed that ELS (extra long staple) Bt cotton responded significantly to poly mulch + drip method. Application of 100 per cent RDF with either foliar spraying of 0.15 per cent boron as solubor during flowering to boll development stages or $MgSO_4$ @ 50 kg ha^{-1} as drip fertigation were on par with 100 per cent or 75 per cent of RDF with 50 kg each of $ZnSO_4$, $MgSO_4$ and foliar spraying of boron 0.15 per cent as solubor (Nalayini *et al*., 2012).

Drip fertigation and drip band application of 100 per cent recommended dose of fertilizer of NPK kg ha^{-1} (120:60:60) increased the seed cotton yield by 10.8 and 9.7 per cent during winter and 15.0 and 10.9 per cent during summer seasons respectively as against furrow band application. Adoption of drip fertigation saved 60 kg N ha^{-1} over furrow band application during both seasons. Enhanced cotton quality parameters like ginning percentage, lint index and Bartlett's index were also observed with drip fertigation and drip band application as compared to furrow irrigation (Veeraputhiran, 2000).

Bhalerao *et al.* (2011) found significant response to application of 125 per cent RDF through fertigation in six splits than application of RDF through soil application. Pooled mean indicated that application of 125 per cent RDF through fertigation when recorded significantly higher seed cotton yield (1.97 t ha^{-1}) than other treatments. Fertigation regimes of 10 equal or 10 unequal splits of N and K upto 120 DAS resulted in more sympodia, more bolls and heavier bolls and produced increased seed cotton yield (Avudathai *et al*., 2009). Application of 100 kg N ha^{-1} through drip method recorded significantly higher seed cotton yield over rest of the treatments including conventional method (100 kg N ha^{-1} through soil application) (Tekale *et al*., 2000).

Study conducted at Coimbatore during summer indicated that 75 per cent recommended NPK kg ha^{-1} (60:30:30) through drip fertigation recorded higher seed cotton yield (1,639 kg ha^{-1}) as compared to soil application of recommended fertilizer (782 kg ha^{-1}) (Nalayini and Shanmugham, 2002). Muthuchamy and Subramanian (2004) observed that drip fertigation with 75 per cent recommended dose of fertilizer (120:60:60 kg NPK ha^{-1}) enhanced the number of bolls per plant by 22.5 and seed cotton yield by 1.33 t ha^{-1}, respectively as compared to flood irrigation and soil application of recommended fertilizers.

Reddy and Aruna (2010) at Regional Agricultural Research Station, Nandyal revealed that fertigation with 125 per cent recommended dose of fertilizer of N and K applied in splits with 10 per cent as basal and remaining 90 per cent in nine splits from 30 to120 days recorded higher kapas yield of 2.69 t ha^{-1}. It was concluded that benefits of drip irrigation were with more number of split applications of RDF than the conventional fertilizer application. Rajendran and Arunvenkatesh (2014) at cotton breeding station, TNAU, Coimbatore results showed that drip fertigation with 75 per cent RDF as water soluble fertilizer had significant influence on the growth and yield attributes with increased uptake of major nutrients higher over other treatments. Drip fertigation with 75 per cent RDF which registered the highest seed cotton yield of 3,324 kg ha^{-1}, which was closely followed by drip fertigation with 100 per cent recommended dose of fertilizer of NPK as straight and water soluble fertilizer *viz.*, 3,063 and 3,062 kg yield in high irrigation frequency (0.8 IW/CPE) over no irrigation condition. Application of nutrients through drip fertigation with 75 per cent RDF as water soluble fertilizer improved seed cotton yield by 33.44 per cent compared to conventional surface irrigation with soil application of fertilizer.

Aslam *et al.* (2009) revealed that fertigation showed an edge over broadcast method at all levels of phosphorus application. The seed cotton yield per kg of phosphorus fertigation was 48 per cent higher than the corresponding broadcast application. The studies also showed that fertigation was the most efficient method of P application as compared to the conventional broadcast application of fertilizers.

2.6.2 Effect of fertigation on nutrient distribution

Urea is known to be more relatively mobile in soils and it is not strongly adsorbed by soil colloids. Therefore, it tends to be more evenly distributed within the wetted profile than does the applied ammonium as observed by Laher and Avnimelech (1980). The deeper movement of applied urea would tend to minimize losses of N by ammonia volatilization but increases leaching losses.

Potassium ion is adsorbed on to the cation exchange site on soil colloid so that extent of movement is dependent upon CEC of the soil and the rate at which K applied. Studies have indicated considerable lateral and downward movement of trickle applied potassium. The distribution of K generally is more uniform than that of either nitrate or phosphate. Parchomchuk *et al.* (1993) reported that the K concentration was increased at all the locations below the 20 cm depth immediately following the first fertigation season, which apparently leached from the upper layers where concentration had declined sharply.

Bangar and Chaudhari (2004) at MPKV, Rahuri observed that the available N, P and K contents in the soil were affected by the sources and levels of water soluble fertilizers as well as straight fertilizers applied through drip. The available N, P and K contents in the soil was maximum just beneath the dripper and it moved laterally upto 15 cm and vertically 15 to 25 cm and there after it dwindled.

Hebbar *et al.* (2004) at UAS, Bengaluru reported that lower NO_3-N was observed at 30 to 45 cm soil layer in fertigation treatments with water soluble fertilizers (WSF) with normal fertilizers (NF) fertigation and NK fertigation at 53-55 kg ha^{-1} compared to entirely soil applied treatments. Assimable P distribution in soil at all layers was at higher levels (> 24.2 kg ha^{-1}) and was highest P at 0-15 cm and 15-30 cm than soil application (98.2 kg ha^{-1}) at 111.4 kg ha^{-1}. Exchangeable K accumulation was higher at deeper layers (45-60 cm) in furrow (92.9 kg ha^{-1}) and drip irrigation (95.4 kg ha^{-1}) where entire K fertilizer was applied once, indicating potential leaching risks.

2.6.3 Effect on nutrient uptake and use efficiency

Balasubramanian *et al.* (2000) reported saving of 25 per cent fertilizer through fertigation. Besides, as nutrients are supplied along with the water in the root zone through drip system, root proliferation was greater when the nutrients were applied to root zone resulting in enhanced uptake of nutrients and water. Similarly Avudaithai *et al.* (2009) at Madurai, Tamil Nadu found significant effect of fertigation regimes on nutrient uptake and nitrogen use efficiency in hybrid cotton. Veeraputhiran and Chinnusamy (2005) also reported that drip fertigation substantially increased the nutrient use efficiency compared to furrow irrigation with band application.

Nitrogen uptake was significantly increased with the use of the drip fertigation method compared with surface irrigation coupled with soil application of fertilizers. Nitrogen uptake ranged between 28 g for the surface irrigated treatment and 47.5 g for the comparative drip fertigated treatment. It was concluded, based on this, that under drip fertigation more fertilizer N is taken up and utilized for the production of seed cotton yield (Mussaddak, 2004).

Nutrient use efficiency under fertigation could be as high as 90 per cent compared to 25 to 35 per cent in conventional methods. The amount of fertilizer lost through leaching could be as low as 10 per cent in fertigation where as it is 50 per cent in traditional system (Solaimalai *et al*., 2005).

2.6.4 Economics of Bt cotton as influenced by drip fertigation

Rajendran and Arunvenkatesh (2014) at cotton breeding station, TNAU, Coimbatore reported that highest benefit cost ratio of 2.14 recorded with drip fertigation with 100 per cent RDF as straight fertilizers with the net return of 40,760.20 ha^{-1} followed by benefit cost ratio of 1.99 with the highest net return of ` 41,374.15 $ha^{-1}$ was noticed in drip fertigation with 75 per cent RDF as water soluble fertilizers. Surface irrigation with soil application of 100 per cent RDF as straight fertilizers recorded the least net return and benefit cost ratio of ` 3,244ha^{-1} and 1.13 respectively. Higher gross returns (` 1,12,101 $ha^{-1}$), net returns (` 79,231 ha^{-1}) and B:C ratio (3.41) was recorded with 100 per cent RDF with fertigation in 5 splits as compared to all other treatments (Bharathraj *et al*., 2015). Studies at Turkey found that among irrigation levels, net return values decreased from T_{100} (received 100 per cent irrigation) treatment to T_{25} (received 25 per cent irrigation) treatment and T_{100} was found to be the most profitable. The reduction in the net income of the T_{25} and T_{50} (received 50 per cent irrigation) treatment was significant and seemed to be non-profitable (Dagdelen *et al.*, 2009).

Bangar and Chaudhari (2004) reported that the total cost for water soluble fertilizers (WSF) and straight fertilizers (SF) were ` 1,05,280 $ha^{-1}$ and ` 88,576 ha^{-1}, respectively. The benefit cost ratios were in the order of 1.04 and 1.18. Total net income accrued was found to be maximum with SF (` 1,04,380 $ha^{-1}$) followed by WSF (` 1,03,980 ha^{-1}) and surface (` 50,200 ha^{-1}) treatments.

3. MATERIAL AND METHODS

The field experiment was conducted at Agricultural Research Station, Dharwad farm, Dharwad, during *kharif* 2016-2017 on Effect of conventional and water soluble fertilizers through fertigation on growth, yield and quality parameters of Bt cotton. Details of the materials used and methods adopted during the investigation are furnished below.

3.1 Location of the experimental site

The experiment was conducted during *kharif* season in Agronomy field unit at Agricultural Research Station (ARS), Dharwad farm (Plot No. 4 of Block ‘D’), University of Agricultural Sciences Dharwad. Geographically, Dharwad is situated in the Northern Transition zone (Zone 8) of Karnataka on latitude 15^0 07' North, longitude of 76^0 06’ East and at an altitude of 678 m above the mean sea level.

3.2 Soil and its characteristics

The soil of experimental site was medium deep black soil (*Vertic Inceptisol*). Composite soil samples were drawn before start and after harvest of experimental site. The soil was air dried, powdered and allowed to pass through 2 mm sieve and was analyzed for physical and chemical properties. The values obtained along with the methods adopted for their estimation are furnished in Table 1.

3.3 Climatic conditions

The data on climatic parameters such as rainfall, temperature (maximum and minimum) and relative humidity recorded at Agricultural Research Station (ARS), Dharwad farm during cropping period of 2016-17 and for the past 66 years is furnished in Table 2 and figure 1. The total rainfall of 537.5 mm was received during a crop growing season. Higher amount of rainfall was received during July month *i.e.*, 151.8 mm. The mean maximum temperature recorded during crop growth period was highest during April (38.04 °C) whereas, minimum was during January (14.05 °C). The monthly relative humidity was maximum during August (92.71 per cent), while minimum was in November (57.17 per cent).

Table 1: Physical and chemical properties of the experimental site

Sl. No.	Particulars	Value	Method
I.	**Physical properties**		
1.	**Particle size analysis**		
a	Coarse sand (per cent)	8.40	International Pipette method (Piper, 2002)
b	Fine sand (per cent)	13.90	
c	Silt (per cent)	16.20	
d	Clay (per cent)	61.50	
e	Texture	Clay	
II.	**Chemical properties**		
1.	pH (1: 2.5 soil: water extract)	7.2	Potentiometric method (Sparks, 1996)
2.	Electrical conductivity (dS m^{-1}) (1: 2.5 soil: water extract)	0.34	Conductivity method (Sparks, 1996)
3.	Organic carbon (g kg^{-1})	0.4	Walkley and Black wet oxidation method (Sparks,1996)
4.	Available nitrogen (kg ha^{-1})	236.8	Alkaline permanganate method (Sharawat and Buford, 1982)
5.	Available phosphorus (kg ha^{-1})	27.2	Olsen's method (Jackson, 1973)
6.	Available potassium (kgha^{-1})	356.6	Flame photometer method (Sparks, 1996)

Table 2: Monthly mean meteorological data for the experimental year (2016) and the mean of past 66 years (1950-2015) at the Agricultural Research Station, Dharwad Farm

Month	Rainfall (mm)		Rainy days (2016)	Mean temperature (^oC)				Relative humidity (%)	
				Maximum		Minimum			
	2016	1950-2015		2016	1950-2015	2016	1950-2015	2016	1950-2015
January	--	0.8	--	30.07	28.70	14.05	14.00	59.81	52.60
February	1.0	11.0	--	33.59	31.70	17.87	15.35	63.28	42.55
March	0.8	3.4	--	36.14	34.05	20.64	18.95	59.58	48.65
April	29.0	48.2	4	38.04	35.85	21.54	20.65	73.20	50.20
May	68.0	25.4	5	36.03	34.95	22.10	21.50	80.74	62.10
June	109.0	105.2	10	29.20	29.50	21.32	21.40	90.83	84.50
July	151.8	152.2	16	26.27	28.00	20.96	21.00	92.35	81.55
August	82.2	100.6	9	26.39	28.00	20.60	20.50	92.71	81.55
September	45.6	106.5	5	27.05	28.90	20.08	20.40	90.00	79.55
October	35.3	126.3	2	29.76	30.35	18.81	19.30	75.61	68.05
November	14.8	31.5	1	30.84	29.45	14.53	16.75	57.17	64.60
December	--	5.3	--	29.98	29.20	14.05	15.10	59.47	60.05
Total	**537.5**		**52**	-	-	-	-	-	-

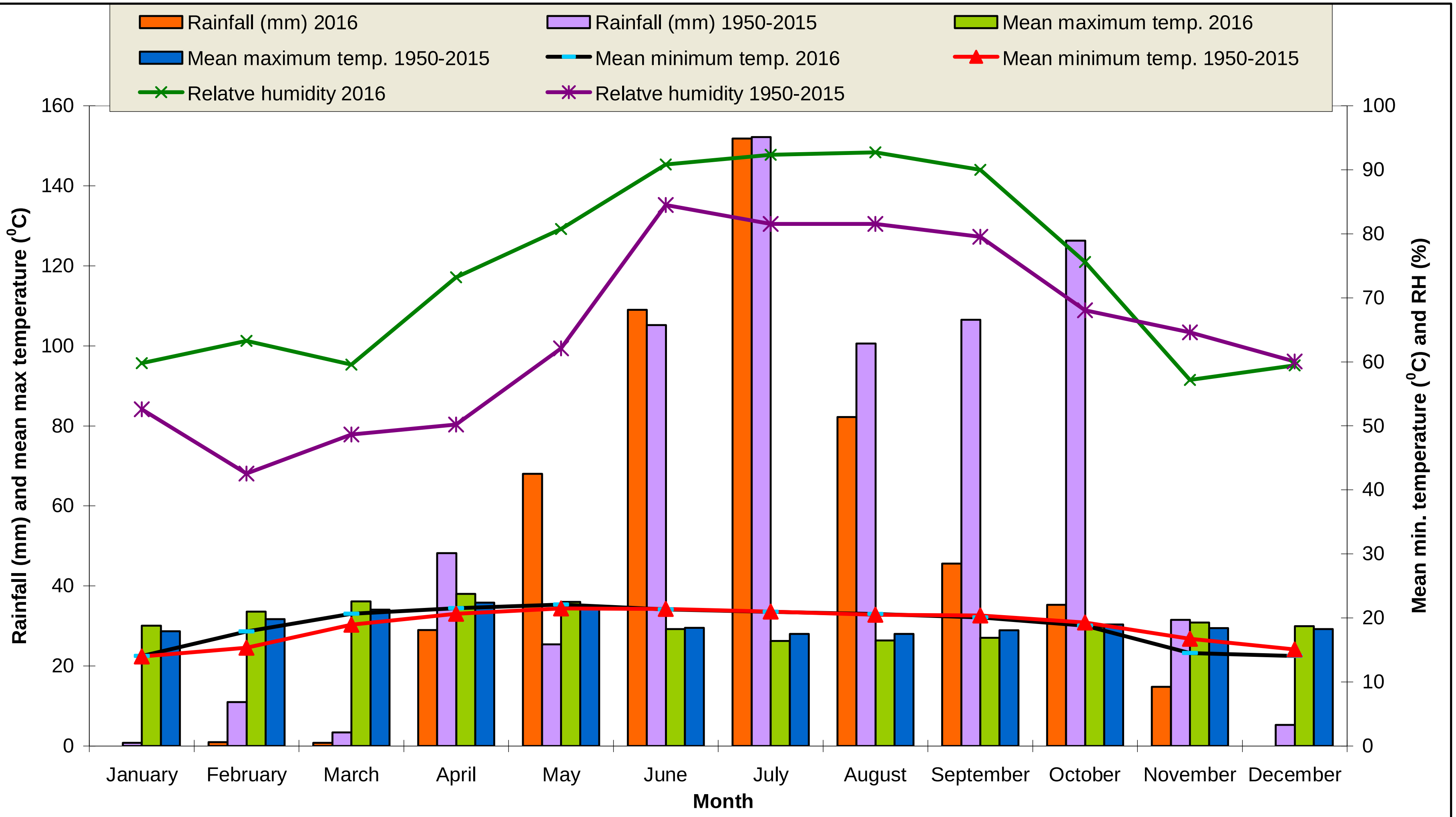

Fig. 1: Monthly mean meteorological data for the experimental year (2016) and the mean of past 65 years (1950-2015) at the Agricultural Research Station, Dharwad Farm

3.4 Previous crop in the experimental area

Cotton crop was grown during *kharif* 2015-16 with normal cultivation practices.

3.5 Experimental details

The experimental details like design and layout, plot size, treatments, crop and cultural practices adapted during experimentation are given below.

3.5.1 Treatment details

T_1: Fertigation of 30 per cent RDF through water soluble fertilizer (WSF) (45: 22.5: 22.5 N: P_2O_5: K_2O kg ha^{-1})

T_2: Fertigation of 25 per cent RDF through WSF (37.5: 19: 19 N: P_2O_5: K_2O kg ha^{-1})

T_3: Fertigation of 20 per cent RDF through WSF (30: 15: 15 N: P_2O_5: K_2O kg ha^{-1})

T_4: Fertigation of 15 per cent RDF through WSF (22.5: 11: 11 N: P_2O_5: K_2O kg ha^{-1})

T_5: Fertigation of 25 per cent RDF through conventional fertilizer (37.5: 19: 19 N: P_2O_5: K_2O kg ha^{-1}) + T_1

T_6: Fertigation of 25 per cent RDF through conventional fertilizer + T_2

T_7: Fertigation of 25 per cent RDF through conventional fertilizer + T_3

T_8: Fertigation of 25 per cent RDF through conventional fertilizer + T_4

T_9: Fertigation of conventional fertilizers with 100 per cent RDF

Note: RDF for Bt cotton is 150: 75: 75 N: P_2O_5: K_2O kg ha^{-1}

Water soluble fertilizer (WSF): 19: 19: 19 (19: 19: 19) and urea.

Drip irrigation at 1.0 Etc

Fertigation in six equal splits at an interval of 15 days each at 15, 30, 45, 60, 75 and 90 days after sowing (DAS).

3.5.2 Design and layout

The Experiment was laid out in Randomized Complete Block Design (RCBD) with three replications. The plan of layout is illustrated in Fig. 2 and general view of the experimental plot is depicted in Plate 1.

Location	: Agricultural Research Station, Dharwad farm, Dharwad
Season	: *Kharif* (2016)
Crop	: Bt Cotton
Design of experiment	: Randomized Complete Block Design (RCBD)
Replications	: 3
Gross plot size	: 7.2 m × 6 m (43.2 sq. m)
Net plot size	: 5.4 m × 4.8 m (25.92 sq. m)
Spacing	: 120 cm–60 cm–120 cm (paired row)
Genotype	: Ajit-155 BG-II
Irrigation at	: 1.0 Etc

3.5.3 Installation of drip irrigation unit

The drip irrigation unit was installed in the experimental site measuring 7.2 m in length and 6 m in width as per treatments. The unit consisted of four stage filter system with a mesh of 100 and 80 microns, water meter, control valve and air exhaust valve attached in series to the main PVC line of 50 mm diameter. The sub main pipe of 40 mm diameter and laterals of 12.5 mm diameter and point source adjustable emitters connected to the laterals were other components of the drip unit.

Emitters here refer to point source emitters which discharge water at the rate of four litres per hour (4 lph) from individual out let at very low pressure literally drop by drop. In paired row planting system, one lateral connected with emitters was placed

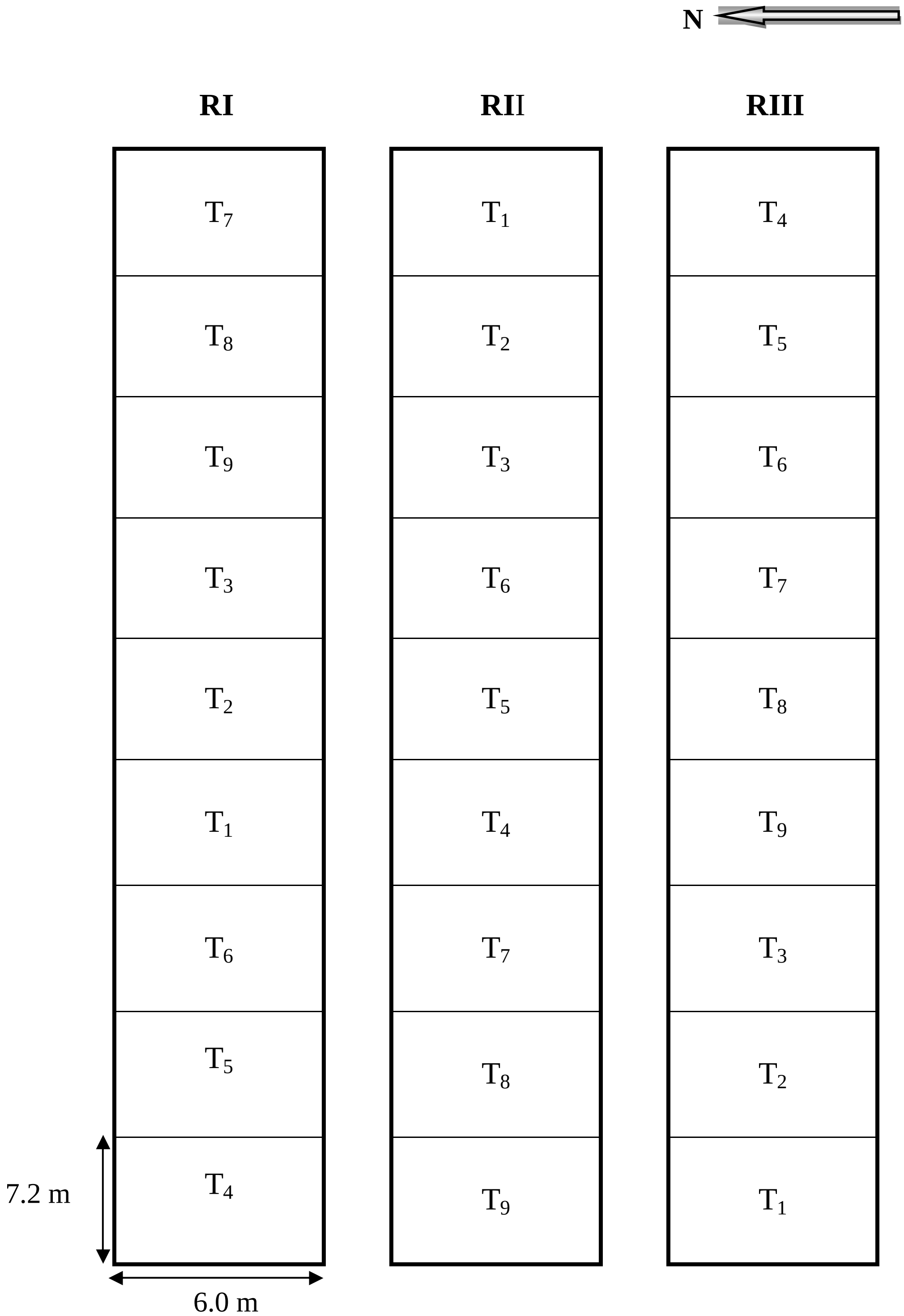

Fig. 2: Plan and layout of the experiment

30 DAS

60 DAS

At harvest

Plate 1: General view of experimental plot

between two rows of each pair. One emitter was placed for every two plants in paired row system.

3.5.4 Irrigation

Irrigation treatment was set at 1.0 Etc level. Scheduling of irrigation was done by using crop coefficient factors during cotton growth period and pan coefficient at every three days interval by considering rainfall using the following formula.

$$V = E_0 \times Kc \times Kp \times A \times 2$$

V : Volume of water to be given through drip for two plants (l)

E_0 : Pan evaporation of two days (mm)

Kc : Crop factor as per growth stages of cotton

Kp : Pan factor (0.70)

A : Area to be irrigated (Spacing)

Kc : Crop Coefficient factors during cotton growth period

0-25 Days after sowing (DAS): 0.45

26-70 DAS : 0.75

71-120 DAS : 1.15

121 to harvest : 0.70

Volume of water to be given for 1.0 mm evaporation for 0-25 days old crop

$= [1.0 \times 0.4 \times 0.7 \times (0.9 \times 0.6) \times 2]$

(0.9×0.6) sq. m = Area covered by each plant

= 0.3024 l

= 302 ml

Considering the drip efficiency as 85 per cent the water to applied

For 100 per cent PE (1.0 ETc): (302 × 100)/85 = 355 ml

Time of operation for 4 lph dripper for 1 mm daily pan evaporation:

For 100 per cent PE (1.0 ETc): (355× 60 minutes)/4000 ml = 5.3 (around 6 minutes)

3.6 Details of cultivation

3.6.1 Land preparation

The land was ploughed by tractor drawn cultivator once and followed by two harrowing. The land was prepared to a fine seed bed and the experiment was laid out according to the plan.

3.6.2 Manures and fertilizer application

Well decomposed FYM @ 10 t ha^{-1} was incorporated into soil three weeks prior to sowing. The source of nitrogen, phosphorus and potassium were applied in the form of water soluble fertilizer (19: 19: 19 and urea) and conventional fertilizers *viz.,* urea, single super phosphate and muriate of potash. Fertilizer dose of 150: 75: 75 N: P_2O_5: K_2O kg ha^{-1} was recommended dose of fertilizer (RDF). Variable rates of fertilizer doses as per different treatments were calculated based on the gross plot size. Nitrogen and potassium fertigation was done in six equal spilts and fertigation was given at an interval of 15 days each. Entire dose of (100 per cent) P_2O_5 was applied as basal in conventional fertilizer treated plots. Basal dose of fertilizers were applied five centimeter away and deep from the seed by ring method.

3.6.3 Seeds and sowing

The Ajit- 155 (BG- II) hybrid cotton was dibbled as per the specification in paired row sowing on 20th June 2016. Two seeds per hill were dibbled to a depth of 5 cm on flat bed.

3.6.4 Fertilizer application

3.6.4.1 Calculation of quantity of fertilizer as per treatments

Quantity of fertilizer was worked out according to treatments.

3.6.5 After care

3.6.5.1 Gap filling

Gap filling was done 6 days after sowing.

3.6.5.2 Thinning

Thinning was done at 15 days after sowing retaining one seedling per spot.

3.6.5.3 Weeding and inter cultivation

One inter cultivation at 30 and two hand weedings at 45 and 65 DAS were carried out to keep the plots free from weeds and for better aeration and also earthing up of soil was done to prevent the lodging of plants.

3.6.5.4 Plant protection schedule

The common plant protection measures as per package of practices for Bt cotton for sucking pests (jassids, thrips, aphids, mite, mirid bugs, midges and white flies) were adopted in all the treatments.The details of spraying chemicals, doses and schedule of spray is furnished below.

Chemical name	Dosage	Schedule of spray (DAS)
Curacron	2.00 l ha^{-1}	45
Contaf	1.00 l ha^{-1}	50
Polo	0.75 kg ha^{-1}	60
Proclaim	0.25 kg ha^{-1}	60
Regent	1.00 l ha^{-1}	70
Acephate	2.00 kg ha^{-1}	90
DDVP	0.50 l ha^{-1}	100

Calculation of quantity of fertilizers

Treatments	Nutrients through WSF (kg ha^{-1})			Through Conv. Fertilizer (kg ha^{-1})			Fertilizer for gross plot (g/43.2 sq.m)				Application of fert. at each interval (g/43.2 sq.m)			
	N	**P_2O_5**	**K_2O**	**N**	**P_2O_5**	**K_2O**	**19: 19: 19**	**Urea**	**MOP**	**SSP**	**19: 19: 19**	**Urea**	**MOP**	**SSP**
T_1	45	22.5	22.5	-	-	-	512	211	-	-	85.3	35.2	-	-
T_2	37.5	19	19	-	-	-	432	174	-	-	72	29	-	-
T_3	30	15	15	-	-	-	341	141	-	-	57	23.5	-	-
T_4	22.5	11	11	-	-	-	250	108	-	-	42	18	-	-
T_5	45	22.5	22.5	37.5	19	19	512	563	136	513	85.3	94	23	513
T_6	37.5	19	19	37.5	19	19	432	526	136	513	72	88	23	513
T_7	30	15	15	37.5	19	19	341	493	136	513	57	82	23	513
T_8	22.5	11	11	37.5	19	19	250	460	136	513	42	77	23	513
T_9	-	-	-	150	75	75	-	1406	538	513	-	352	135	2025

3.6.6 Harvesting

Kapas picking from the net plot and border rows was done separately in two pickings, first picking on 13th November 2016 and second on 29th December 2016.

3.7 Collection of experimental data

3.7.1 Sampling procedure

In each plot, five plants were selected randomly and tagged for the purpose of recording morphological, biochemical and yield parameters at 30, 60, 90, 120,150 DAS and at harvest. Observations were recorded from the net plot whereas, destructive sampling was done in the border rows. Procedure and the units of the various biometric observations are presented below.

3.7.2 Growth components

3.7.2.1 Plant height

The perpendicular distance from ground level to the tip of fully opened leaf of main shoot on five randomly selected and tagged plants at 30, 60, 90, 120, 150 DAS and at harvest was recorded. The average height was computed and expressed in centimeters per plant.

3.7.2.2 Dry matter production and partitioning

Dry matter accumulation was studied for only above ground portions of the plant at 30, 60, 90, 120, 150 DAS and at harvest. The plant was uprooted from soil and the samples were first air dried and then oven dried at 50 ^{0}C till they attained constant weight. The weight was recorded by partitioning the plant *viz.,* stem, leaf and reproductive parts and was expressed in grams per plant.

3.7.3 Physiological observations

3.7.3.1 Leaf Area index

The leaf area index plant^{-1} was calculated at 30, 60, 90, 120, 150 days after sowing (DAS) and at harvest by using the formula given by Sestak *et al.* (1971). Leaf area at 30, 60, 90, 120, 150 days after sowing (DAS) and at harvest was measured by using LI-3000A portable leaf area meter.

$$LAI = \frac{\text{Leaf area plant}^{-1}\ (dm^2)}{\text{Land area plant}^{-1}\ (dm^2)}$$

3.7.3.2 Leaf area duration

Leaf area duration was worked out between 30-60, 60-90, 90-120, 120-150 and 150 DAS to at harvest by adopting the formula given by Power *et al.* (1969) and expressed in days.

$$LAD = \frac{L_1 + L_2}{2} \times (t_2 - t_1)$$

Where,

L_1 = LAI at t_1 stage

L_2 = LAI at t_2 stage

$(t_2 - t_1)$ = Time interval between t_1 and t_2 stage (days)

3.7.3.3 Chlorophyll content in leaf

Leaf chlorophyll content was estimated non destructively by measuring leaf greenness using a portable SPAD-502 (Soil Plant Analysis Development) meter (Minolta Camera Co. Ltd., Japan). Reading was taken from fully expanded leaf in between the leaf margin and the midrib. The average of five SPAD values was taken as the final value. The reading was recorded at 30, 60, 90, 120 and 150 DAS and at harvest.

3.7.3.4 Leaf reddening

Leaf reddening at 70, 90 and 120 days after sowing (DAS) was recorded by visual observation as per National Centre for Integrated Pest Management (NCIPM), technical bulletin 30 (Anon., 2013). For scoring intensity, a system of 0 to 9 grades was developed which was based upon the leaf area covered with red colouration. Up to 70

DAS, Bt cotton plants were not showing the symptoms of leaf reddening, hence not recorded.

Grade	Leaf with reddening symptoms
0	No leaf reddening
1	1 or less than 1 per cent leaf area covered
3	1 to 10 per cent leaf area covered
5	11 to 25 per cent leaf area covered
7	26 to 50 per cent leaf area covered
9	More than 50 per cent leaf area covered

3.7.4 Yield and yield attributing parameters

3.7.4.1 Number of monopodia per plant

The monopodia bearing at least one functional sympodia were counted separately in five tagged plants and recorded at 30, 60, 90,120,150 DAS and at harvest. The average value of these five plants was expressed as number of monopodia per plant.

3.7.4.2 Number of sympodia per plant

Fruiting branches arising from the main stem were counted separately in the five tagged plants and recorded at 30, 60, 90, 120,150 DAS and at harvest. Mean of these five tagged plants was expressed as number of sympodia per plant.

3.7.4.3 Number of bolls per plant

Total number of bolls were recorded from five tagged plants at harvest in all the treatments. The mean of these five plants was taken as number of bolls produced per plant.

3.7.4.4 Good and bad opened bolls per plant

The number of good opened bolls (GOB) and bad opened bolls (BOB) per plant were counted separately in the five tagged plants at harvest and from this mean boll number of good and bad opened bolls per plant was worked out.

3.7.4.5 Mean boll weight

Twenty fully opened bolls were selected randomly from each plot and the boll weight of cotton was computed and expressed in gram per boll at harvest.

3.7.4.6 Seed cotton yield per plant

The total seed cotton yield from all the picking from five tagged plants was recorded and the average was presented as seed cotton yield per plant.

3.7.4.7 Seed cotton yield per hectare

At every picking, seed cotton in each net plot was harvested separately, weighed and recorded. After complete harvesting, weight of seed cotton obtained at each picking was added with previous pickings. Besides, yield obtained from other observations taken on net plot was also added and recorded as net plot yield. On the basis of seed cotton yield recorded per net plot, the seed cotton yield per hectare was computed and expressed as seed cotton yield in kilogram per hectare (kg ha^{-1}).

3.7.4.8 Stalk yield

After completion of picking of seed cotton, the stalks were sun dried completely and weight of stalk was recorded per net plot. Stalk yield per hectare was computed based on stalk yield recorded per net plot and expressed as stalk yield in kilogram per hectare (kg ha^{-1}).

3.7.4.9 Harvest index

Harvest index was calculated by using the formula given by Donald (1962).

$$\text{Harvest index} = \frac{\text{Economic yield (kg ha}^{-1}\text{)}}{\text{Biological yield (kg ha}^{-1}\text{)}}$$

3.7.5 Fibre quality parameters

3.7.5.1 Sample preparation

Seed cotton was randomly selected and picked from each treatment during harvesting. Thus collected seed cotton was hand cleaned for dried leaves, insect damaged bolls and subjected for ginning. Cleaned and ginned lint samples of about 100 g was packed and labelled for quality testing.

3.7.5.2 High volume instrument system (HVI)

Various conventional instruments are integrated into a single compact operating system by using the state of the art technology in optics, mechanics and electronics. HVI system provides measurement of Fibre span length (mm), Fibre fineness (µg $inch^{-1}$), Fibre strength (g tex^{-1}), Fibre maturity ratio and Uniformity ratio. Cotton samples were tested for fibre quality parameters from Sujwala Bio Fuels, KIADB Industrial area, Belur, Dharwad with Compact HVI instrument (in ICC mode) by the method adopted from ASTM D-5867 procedure (Sundaram, 2002).

3.7.5.3 2.5 per cent fibre span length

It is the distance spanned by a specified per cent of the fibres in the test beard. 2.5 per cent span length is the distance from the clamp on a fibre beard to a point up to which only 2.5 per cent of the fibres extend (Sundaram, 2002). It was expressed as 2.5 per cent span length in mm.

3.7.5.4 Fibre fineness

It is the measure of fibre weight in µg $inch^{-1}$ length of fibre. Fibre fineness is another important quality characteristic, which plays a prominent role in determining spinning performance of cotton. Fibre fineness denotes the size of the cross sectional dimension of the fibre (Sundaram, 2002). It is also called as micronaire value.

3.7.5.5 Fibre strength

It denotes the maximum tension at which the fibre is able to sustain before it breaks. It can be defined as the ratio of the breaking strength of a bundle of fibre to its weight and expressed in g tex^{-1} (Sundaram, 2002). It is also called as bundle strength.

3.7.5.6 Fibre uniformity ratio

It is the ratio of 50 per cent span length to 2.5 per cent span length and expressed as percentage (Sundaram, 2002).

3.7.5.7 Seed index

It is the weight of 100 seeds (g).

3.7.5.8 Ginning out turn (GOT)

Seed cotton obtained from all the pickings from in each net plot was mixed thoroughly and 300 g sample was drawn. This seed cotton was ginned with mechanical ginner and the ginning out turn was calculated by the following formula.

$$\text{Ginning out turn (\%)} = \frac{\text{Weight of lint (g)}}{\text{Weight of seed cotton (g)}} \times 100$$

3.7.5.9 Lint index

Lint index is the absolute weight of lint obtained from 100 seeds and was calculated by the following formula.

$$\text{Lint index (\%)} = \frac{\text{Weight of 100 seeds x GOT}}{\text{100 - GOT}}$$

3.7.6 Use efficiencies

3.7.6.1 Nutrient use efficiency

It was worked out by relation of economic crop yield with total quantity of nutrient used.

$$\text{NUE (kg kg}^{-1}\text{)} = \frac{\text{Economic crop yield (kg)}}{\text{Total nutrient applied (kg)}}$$

3.7.6.2 Nitrogen use efficiency

It was worked out by the ratio of economic crop yield in experimental plot and total quantity of nitrogen fertilizer applied to that plot.

$$\text{NUE (kg kg}^{-1}\text{)} = \frac{\text{Yield of treatment plot (kg)}}{\text{Amount of nitrogen applied (kg)}}$$

3.7.6.3 Potassium use efficiency

It was worked out by the ratio of economic crop yield in experimental plot and total quantity of potassium fertilizer applied to that plot.

$$\text{KUE (kg kg}^{-1}\text{)} = \frac{\text{Yield of treatment plot (kg)}}{\text{Amount of potassium applied (kg)}}$$

3.7.7 Soil analysis

3.7.7.1 Collection and preparation of soil samples

Composite soil samples were collected from 0 to 30 cm depth just before lay out of the experiment and after harvest. The soil samples were analyzed for organic carbon, available nitrogen, phosphorus and potassium using standard procedure as given below.

3.7.7.2 Methodology used for soil analysis

Soil sample preparation	Samples collected were air dried in shade, powered and passed through 2 mm sieve and stored.
pH	Soil pH was measured in soil water suspension ratio 1:2.5 by using glass electrode pH meter (Jackson, 1967).
Available nitrogen (kg ha^{-1})	Nitrogen in soil was estimated by following alkaline permanganate method (Subbiah and Asija, 1956).

Available phosphorus (kg ha^{-1})	Available phosphorus was extracted with Olsen's extractant and was estimated by chlorostannous reduced phosphomolybdate blue colour method using spectrophotometer at wavelength of 660 nm (Jackson, 1973)
Available potassium (kg ha^{-1})	Available potassium in soil was extracted by neutral ammonium acetate and subsequent estimation was by flame photometry (Jackson, 1973).
Organic carbon (%)	The organic carbon content of a finely ground soil sample was determined by Walkely and Blacks wet oxidation method as described by Jackson (1967).
Electrical conductivity (EC)	Electrical conductivity was determined in 1:2.5 soil: water suspension using conductivity bridge and expressed as dS m^{-1} (Jackson, 1973).

3.7.8 Plant analysis

Treatment wise plant samples were collected by uprooting the entire plant carefully. The samples were dried in shade and then oven dried at 65 ^{0}C. Then the plant samples were powdered separately into leaf, stem and reproductive parts with the help of grinder and stored in butter paper bags. The samples were analyzed for total nitrogen, phosphorus and potassium content at 60, 90, 120, 150 DAS and at harvest by following standard procedures.

3.7.8.1 Methodology used for plant analysis

Preparation of sample	Destructive plant sample for dry weight estimation was used for plant analysis. Nitrogen, phosphorus, potassium content in whole plant was analyzed at the end.
Total nitrogen (%)	Total nitrogen content on dry weight basis was determined by modified Kjeldahl's method (Jackson, 1973)

Phosphorus content (%)	Plant samples were digested with triacid mixture. The phosphorus content on dry weight basis was determined by vanadomolybdic phosphoric acid yellow colour method in HNO_3 system (Jackson, 1967)
Potassium content (%)	Potassium content on dry weight basis was determined by feeding digested plant sample to flame photometer (Jackson, 1967)

3.7.8.2 Nutrient uptake by plant

Based on nutrient content of plants and dry matter production, uptake of nitrogen, phosphorus and potassium were worked out by using following formula.

$$\text{Nutrient uptake (kg ha}^{-1}\text{)} = \frac{\text{Per cent nutrient concentration}}{100} \times \text{Biomass (kg ha}^{-1}\text{)}$$

3.8 Leaf *Cry* protein concentration (Endotoxin concentration)

Fully opened leaf samples from top portion of the plant were collected from each plot. Each sample was immediately transferred to ice box and brought to laboratory for further analysis as per the protocol provided with quantification kit. Leaf cry protein concentration is expressed as micrograms per gram of fresh leaf weight (µg g^{-1} of fresh leaf weight).

3.8.1 Delta-Endotoxin quantification protocol

Sample preparation

- 50 mg of lyophilized leaf tissue from each leaf sample was placed in 1.5 ml micro centrifuge tube.
- 500 µl of ice-cold 1X sample extraction buffer was added (add 0.2 g powder A and 12 g powder B to 100 ml sample extraction buffer prepared freshly at the time of sample extraction).
- Tissue was macerated at 30 rpm using a motor driven pestle for 30 sec.
- The contents were chilled on ice for 10 min and again macerated for 30 sec.
- The contents were spinned at 8,000 rpm for 15 min and supernatant was pipette out.

Preparation of positive and negative QC seed extracts

- 20 mg of positive and negative seed samples crushed in 500 µl 1X Buffer A, spinned for 5 min in microcentrifuge and 100 ml of each supernatant was used per well.

Standard curve generation for *Cry* 1Ac

- 20 ng ml^{-1} working standard solution was prepared from 1 µg of stock standard ml^{-1} *Cry 1A*c stock solution provided in 1X diluent buffer. Other quantification standards were prepared as under.

Std. No.	Quantification standards scheme	1X diluents buffer (ml)	*Cry 1Ac* conc. (ng ml^{-1})
1	500 µl of 20 ng ml^{-1} *Cry 1Ac* solution	500	20
2	500 µl of std 1	500	10
3	500 µl of std 2	500	5
4	500 µl of std 3	500	2.5
5	500 µl of std 4	500	1.25
6	500 µl of std 5	500	0.625

Anti-*Cry 1Ac* (Ab2) preparation: Anti-*Cry* 1Ac 1:1000 diluted in 1X diluents buffer and added @ 150 µl to each well in the plate.

Standard curve generation for *Cry 2Ab*

160 ng ml^{-1} working standard solution was prepared from 16 µl stock standard ml^{-1} *Cry 2Ab* stock solution provided in 1X diluent buffer. Other quantification standards were prepared as under.

Std. No.	**Quantification standards scheme**	**1X diluents buffer (ml)**	***Cry 1Ac* conc. (ng ml^{-1})**
1	500 µl of 160 ng ml^{-1} *Cry 2Ab* solution	500	80
2	500 µl of std 1	500	40
3	500 µl of std 2	500	20
4	500 µl of std 3	500	10
5	500 µl of std 4	500	5
6	500 µl of std 5	500	2.5

Anti-*Cry 2Ab* (Ab2) preparation: Anti-*Cry 2Ab* 1:1000 diluted in 1X diluents buffer and added @ 150 µl of Ab2 to each well in the plate.

Plate loading

- Exactly 100 µl of each buffer, standards, positive and negative controls and diluted samples in 1X diluent buffer added in the wells. The plate was incubated at 37 ^{0}C for 1.5 hour in humid environment.

- After incubation samples were discarded and the plate was washed with 1X wash buffer (wash buffer: 100 ml of 10X Buffer A diluted to 1lit. using distilled water).

- Plate was dried by tapping on paper towel.

- AP-conjugated Ab was diluted to 1:1000 in 1X diluent Buffer and added 150 µl per well.

- The contents in plate were mixed and incubated at 37 ^{0}C for 45 min. in humid environment.

- Again contents of the plate were discarded and the plate was washed three times using 1X wash buffer, allowing the plate to stand for 5 min. with wash buffer in the well between washes.

- Plate was dried on paper towel.
- Substrate preparation: 1mg ml^{-1} pNPP solution was freshly prepared in 1X substrate buffer and added @ 250 µl per well.
- Plate was immediately transferred to dark place and incubated exactly for 30 min. Stop solution was added after 30 min
- Absorbance of plate was read at 405 nm after setting one of the blank as blank using Microplate reader.
- Standard curve was plotted with standard protein concentration on X-axis and OD values on Y- axis.
- *Cry 1Ac* and *Cry 2Ab* concentration of each sample was determined by finding its OD value and the corresponding concentration level from graph.
- Dry weight expression level: Dry weight levels for leaf tissues were calculated as follows.

$$\text{Dry weight } (\mu g\ g^{-1}) = \frac{(\text{ng ml}^{-1} \text{ value from linear plot}) \times (\text{T: B ratio})}{100}$$

3.9 Economics of cotton cultivation

The cost of cultivation and gross returns per hectare for each treatment was computed based on the price of inputs and outputs that were prevailing at the time of their use and harvest. The net return per hectare was calculated by deducting the cost of cultivation from the total monetary value of the produce (Appendix I and II). Benefit cost ratio was calculated as under

$$\text{Benefit cost ratio} = \frac{\text{Gross returns (` ha}^{-1})}{\text{Cost of cultivation (` ha}^{-1})}$$

3.10 Statistical analysis and interpretation of data

The data collected from the experiment at different growth stages were subjected to statistical analysis as described by Gomez and Gomez (1984). The level of significance used in 'F' and‘t’ test was P = 0.05. Critical difference (CD) values were calculated wherever the 'F' test was found significant.

4. EXPERIMENTAL RESULTS

The results of the investigation “Effect of conventional and water soluble fertilizers through fertigation on growth, yield and quality parameters of Bt cotton” conducted during 2016-17 are presented in this chapter.

4.1 Growth parameters

4.1.1 Plant height

The data on plant height are presented in Table 3. Plant height of Bt cotton not differed significantly due to different fertigation levels with conventional and water soluble fertilizers.

The plant height increased with each level of fertigation. Paired row sowing with fertigation of 100 per cent recommended dose of fertilizer (RDF) (150:75:75 kg ha^{-1}) through conventional fertilizers applied in six equal splits recorded higher plant height at 30, 60, 90, 120, 150 DAS and at harvest (17.21, 46.10, 112.40, 124.07, 126.80 and 128.87 cm, respectively) over other treatments.

Influence of drip fertigation with only water soluble fertilizers had no significant effect on plant height. However, paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) in six equal splits recorded higher plant height at 30, 60, 90, 120, 150 DAS and at harvest (16.01, 44.33, 103.53, 115.67, 116.33 and 117.13 cm, respectively) compared to others.

Among different treatments involving either fertigation with only water soluble fertilizers or fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers, fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers recorded higher plant height compared to their respective fertigation with water soluble fertilizers only. However, paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits recorded higher plant height at 30, 60, 90, 120, 150 DAS and at harvest (16.91, 45.87, 110.87, 123.40, 124.67 and 124.93 cm, respectively) compared to other treatments.

Table 3: Plant height of Bt cotton as influenced by fertigation levels with conventional and water soluble fertilizers

Treatment	Plant height (cm)					
	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS	At harvest
T_1: Fertigation of 30% RDF through WSF	16.01	44.33	103.53	115.67	116.33	117.13
T_2: Fertigation of 25% RDF through WSF	16.01	44.03	102.53	114.33	115.10	116.33
T_3: Fertigation of 20% RDF through WSF	15.88	43.80	102.33	112.73	114.53	115.53
T_4: Fertigation of 15% RDF through WSF	15.48	42.57	101.67	109.80	113.33	114.93
T_5: Fertigation of 25% RDF through CF + T_1	16.91	45.87	110.87	123.40	124.67	124.93
T_6: Fertigation of 25% RDF through CF + T_2	16.84	45.47	109.73	121.10	122.33	124.73
T_7: Fertigation of 25% RDF through CF + T_3	16.48	45.47	104.47	119.73	120.20	119.13
T_8: Fertigation of 25% RDF through CF + T_4	16.08	45.40	104.33	116.80	118.20	118.80
T_9: Fertigation of conventional fertilizers with 100 % RDF	17.21	46.10	112.40	124.07	126.80	128.87
S. Em. ±	0.64	1.34	3.32	3.47	4.66	4.58
C.D. (P = 0.05)	NS	NS	NS	NS	NS	NS

NS: Non significant, DAS: Days after sowing, RDF: 150: 75: 75 N: P_2O_5: K_2O kg ha^{-1}, WSF: Water soluble fertilizer (19: 19: 19)

4.1.2 Dry matter accumulation in stem

The data on dry matter accumulation in stem are presented in Table 4. Dry matter accumulation in stem differed significantly due to different fertigation levels with conventional and water soluble fertilizers.

Influence of different fertigation levels in paired row sowing on dry matter accumulation in stem was significant at all the growth stages except 30 DAS. The data indicated that paired row sowing with fertigation of 100 per cent RDF (150:75:75 kg ha^{-1}) through conventional fertilizers in six equal splits (T_9) recorded significantly higher dry matter accumulation in stem at 60, 90, 120, 150 DAS and at harvest (32.8, 64.4, 94.2, 122.9 and 140.6 g $plant^{-1}$, respectively) over other treatments. However, it was on par with paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) through water soluble fertilizer along with 25 per cent RDF through conventional fertilizers applied in six equal splits (T_5) (31.8, 59.7, 86.9, 112.2 and 131.7 g $plant^{-1}$, respectively) and paired row sowing with fertigation of 25 per cent RDF (37.5: 19: 19 kg ha^{-1}) through water soluble fertilizer and 25 per cent RD through conventional fertilizers applied in six equal splits (T_6) (30.9, 55.7, 84.2, 111.5 and 125.9 g $plant^{-1}$, respectively). Fertigation of 15 per cent RDF (22.5: 11: 11 kg ha^{-1}) applied in six equal splits (T_4) recorded significantly lower dry matter accumulation in stem. At 30 DAS, effect of different fertigation levels on dry matter accumulation in stem was non significant.

Effect of drip fertigation with only water soluble fertilizers had significant effect on dry matter accumulation in stem at all the growth stages except 30 DAS. However, paired row sowing with fertigation of 30 per cent RDF (T_1) (45: 22.5: 22.5 kg ha^{-1}) applied in six equal splits recorded higher dry matter accumulation in stem at 60, 90, 120, 150 DAS and at harvest (27.1, 47.7, 71.0, 101.5 and 111.9 g $plant^{-1}$, respectively) compared to other treatments.

Among different treatments involving either fertigation with only water soluble fertilizers or fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers, fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers recorded higher dry matter accumulation in stem compared to respective fertigation with water soluble fertilizers only. Paired row

Table 4: Dry matter accumulation in stem of Bt cotton as influenced by fertigation levels with conventional and water soluble fertilizers

Treatment	Dry matter accumulation in stem (g plant $^{-1}$)					
	30 DAS	60 DAS	90 DAS	120 DAS	150 DAS	At harvest
T_1: Fertigation of 30% RDF through WSF	7.08	27.13	47.67	70.96	101.46	111.94
T_2: Fertigation of 25% RDF through WSF	7.06	26.02	46.30	68.55	99.05	109.90
T_3: Fertigation of 20% RDF through WSF	7.03	22.87	43.13	67.47	97.64	109.30
T_4: Fertigation of 15% RDF through WSF	6.93	21.96	39.55	64.75	92.08	103.70
T_5: Fertigation of 25% RDF through CF + T_1	7.16	31.78	59.73	86.85	112.17	131.70
T_6: Fertigation of 25% RDF through CF + T_2	7.13	30.90	55.70	84.22	111.55	125.93
T_7: Fertigation of 25% RDF through CF + T_3	7.12	29.00	53.57	77.89	107.36	122.67
T_8: Fertigation of 25% RDF through CF + T_4	7.10	27.72	51.32	74.25	103.89	115.28
T_9: Fertigation of conventional fertilizers with 100 % RDF	7.26	32.81	62.90	97.53	124.25	140.64
S. Em. ±	0.21	0.82	1.92	3.45	3.18	4.08
C.D. (P = 0.05)	NS	2.46	5.75	10.34	9.53	12.23

NS: Non significant, DAS: Days after sowing, RDF: 150: 75: 75 N: P_2O_5: K_2O kg ha^{-1}, WSF: Water soluble fertilizer (19: 19: 19)

sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) through water soluble fertilizer along with 25 per cent RDF through conventional fertilizers applied in six equal splits (T_5) recorded higher dry matter accumulation in stem at 30, 60, 90, 120, 150 DAS and at harvest (7.2, 31.8, 59.7, 86.9, 112.2 and 131.7 g $plant^{-1}$, respectively) compared to others. However, it was on par with paired row sowing with fertigation of 25 per cent RDF (37.5: 19: 19 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_6) (7.1, 30.9, 55.7, 84.2, 111.5 and 125.9 g $plant^{-1}$, respectively).

4.1.3 Dry matter accumulation in leaf

The data on dry matter accumulation in leaf are presented in Table 5. Dry matter accumulation in leaf differed significantly due to different fertigation levels with conventional and water soluble fertilizers.

Influence of different fertigation levels in paired row sowing on dry matter accumulation in leaf was significant at all the growth stages except 30 DAS. The data indicated that paired row sowing with fertigation of 100 per cent RDF (150:75:75 kg ha^{-1}) through conventional fertilizers applied in six equal splits (T_9) recorded significantly higher dry matter accumulation in leaf at 60, 90, 120, 150 DAS and at harvest (31.05, 67.88, 105.23, 68.71 and 51.87 g $plant^{-1}$, respectively) over other treatments. However, it was on par with paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) through water soluble fertilizer along with 25 per cent RDF through conventional fertilizers applied in six equal splits (T_5) (30.02, 63.18, 99.85, 62.51 and 45.67 g $plant^{-1}$, respectively) and paired row sowing with fertigation of 25 per cent RDF (37.5: 19: 19 kg ha^{-1}) through water soluble fertilizer along with 25 per cent RDF through conventional fertilizers applied in six equal splits (T_6) (29.14, 59.15, 97.38, 60.39 and 43.55g $plant^{-1}$, respectively). Paired row sowing with fertigation of 15 per cent RDF (22.5: 11: 11 kg ha^{-1}) applied in six equal splits (T_4) recorded significantly lower dry matter accumulation in leaf. At 30 DAS, effect of different fertigation levels on dry matter accumulation was non-significant.

Effect of drip fertigation with only water soluble fertilizers had significant effect on dry matter accumulation in leaf at all the growth stages except 30 DAS. However, paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) applied

Table 5: Dry matter accumulation in leaf of Bt cotton as influenced by fertigation levels with conventional and water soluble fertilizers

Treatment	Dry matter accumulation in leaf (g plant^{-1})					
	30 DAS	**60 DAS**	**90 DAS**	**120 DAS**	**150 DAS**	**At harvest**
T_1: Fertigation of 30% RDF through WSF	5.23	25.37	51.12	88.45	52.36	35.52
T_2: Fertigation of 25% RDF through WSF	5.21	24.26	49.75	86.04	50.99	34.15
T_3: Fertigation of 20% RDF through WSF	5.18	21.11	46.58	84.96	47.49	30.65
T_4: Fertigation of 15% RDF through WSF	5.08	20.20	45.98	71.73	47.22	30.38
T_5: Fertigation of 25% RDF through CF + T_1	5.31	30.02	63.18	99.85	62.51	45.67
T_6: Fertigation of 25% RDF through CF + T_2	5.28	29.14	59.15	97.38	60.39	43.55
T_7: Fertigation of 25% RDF through CF + T_3	5.27	27.24	58.35	95.14	59.59	42.75
T_8: Fertigation of 25% RDF through CF + T_4	5.25	25.96	56.10	90.40	57.34	40.50
T_9: Fertigation of conventional fertilizers with 100 % RDF	5.41	31.05	67.88	105.23	68.71	51.87
S. Em. ±	0.21	0.82	1.63	4.64	1.69	1.69
C.D. (P = 0.05)	NS	2.46	4.88	13.92	5.07	5.07

NS: Non significant, DAS: Days after sowing, RDF: 150: 75: 75 N: P_2O_5: K_2O kg ha^{-1}, WSF: Water soluble fertilizer (19: 19: 19)

in six equal splits (T_1) recorded higher dry matter accumulation in leaf at 60, 90, 120, 150 DAS and at harvest (25.37, 51.12, 88.45, 52.36 and 35.52 g plant^{-1}, respectively) as compared to other treatments.

Among different treatments involving either fertigation with only water soluble fertilizers or fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers, fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers recorded significantly higher dry matter accumulation in leaf compared to their respective fertigation with water soluble fertilizers only. Paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_5) recorded higher dry matter accumulation in leaf at all the growth stages and was on par with paired row sowing with fertigation of 25 per cent RDF (37.5: 19: 19 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_6).

4.1.4 Dry matter accumulation in reproductive parts

The data on dry matter accumulation in reproductive parts are presented in Table 6. Dry matter accumulation in reproductive parts differed significantly due to different fertigation levels with conventional and water soluble fertilizers.

Influence of different fertigation levels in paired row sowing on dry matter accumulation in reproductive parts was significant at 60, 90, 120, 150 DAS and at harvest. The data indicated that paired row sowing with fertigation of 100 per cent RDF (150:75:75 kg ha^{-1}) through conventional fertilizers applied in six equal splits (T_9) recorded significantly higher dry matter accumulation in reproductive parts at 60, 90, 120, 150 DAS and at harvest (10.75, 73.18, 119.35, 132.25 and 141.56 g plant^{-1}, respectively) over other treatments. However, it was on par with paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) through water soluble fertilizer along with 25 per cent RDF through conventional fertilizers applied in six equal splits (T_5) at 150 DAS and at harvest (122.29 and 132.62 g plant^{-1} respectively). Paired row sowing with fertigation of 15 per cent RDF (22.5: 11: 11 kg ha^{-1}) applied in

Table 6: Dry matter accumulation in reproductive parts of Bt cotton as influenced by fertigation levels with conventional and water soluble fertilizers

Treatment	Dry matter accumulation in reproductive parts (g $plant^{-1}$)				
	60 DAS	**90 DAS**	**120 DAS**	**150 DAS**	**At harvest**
T_1: Fertigation of 30% RDF through WSF	9.13	56.42	97.90	111.58	121.86
T_2: Fertigation of 25% RDF through WSF	9.06	55.05	95.49	109.17	120.19
T_3: Fertigation of 20% RDF through WSF	9.05	51.49	94.08	107.76	119.22
T_4: Fertigation of 15% RDF through WSF	8.96	49.83	88.52	102.54	117.72
T_5: Fertigation of 25% RDF through CF + T_1	9.85	67.04	108.61	122.29	132.62
T_6: Fertigation of 25% RDF through CF + T_2	9.51	64.16	107.99	121.67	126.85
T_7: Fertigation of 25% RDF through CF + T_3	9.49	63.40	103.80	115.77	123.59
T_8: Fertigation of 25% RDF through CF + T_4	9.29	61.40	100.33	113.80	122.20
T_9: Fertigation of conventional fertilizers with 100 % RDF	10.75	73.18	119.35	132.25	141.56
S. Em. ±	0.28	1.80	3.18	3.40	3.64
C.D. (P = 0.05)	0.83	5.39	9.54	10.18	10.92

DAS: Days after sowing, RDF: 150: 75: 75 N: P_2O_5: K_2O kg ha^{-1}, WSF: Water soluble fertilizer (19: 19: 19)

six equal splits (T_4) recorded significantly lower dry matter accumulation in reproductive parts.

Effect of drip fertigation with only water soluble fertilizers had significant effect on dry matter accumulation in reproductive parts at 60, 90, 120, 150 DAS and at harvest. However, paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) applied in six equal splits (T_1) recorded higher dry matter accumulation in reproductive parts at 60, 90, 120, 150 DAS and at harvest (9.13, 56.42, 97.90, 111.58 and 121.86 g $plant^{-1}$, respectively) compared to other treatments.

Among different treatments involving either fertigation with only water soluble fertilizers or fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers, fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers recorded higher dry matter accumulation in reproductive parts compared to their respective fertigation with water soluble fertilizers only. Paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) through water soluble fertilizer along with 25 per cent RDF through conventional fertilizers applied in six equal splits (T_5) recorded higher dry matter accumulation in reproductive parts at 60, 90, 120, 150 DAS and at harvest (9.85, 67.04, 108.61, 122.29 and 132.62 g $plant^{-1}$, respectively) as compared to others.

4.1.5 Total dry matter production

The data on total dry matter production are presented in Table 7. Total dry matter production differed significantly due to different fertigation levels with conventional and water soluble fertilizers.

Influence of different fertigation levels in paired row sowing on total dry matter production was significant at all the growth stages except 30 DAS. The data indicated that paired row sowing with fertigation of 100 per cent RDF (150:75:75 kg ha^{-1}) through conventional fertilizers applied in six equal splits (T_9) recorded significantly higher total dry matter production at 60, 90, 120, 150 DAS and at harvest (74.72, 205.50, 318.75, 321.98 and 329.39 g $plant^{-1}$, respectively) over other treatments. However, it was on par with paired row sowing with fertigation of 30 per cent RDF

Table 7: Total dry matter accumulation of Bt cotton as influenced by fertigation levels with conventional and water soluble fertilizers

Treatment	Total dry matter accumulation (g plant^{-1})					
	30 DAS	**60 DAS**	**90 TDM**	**120 TDM**	**150 TDM**	**At harvest**
T_1: Fertigation of 30% RDF through WSF	12.32	61.63	155.20	257.32	265.40	269.31
T_2: Fertigation of 25% RDF through WSF	12.26	59.35	151.10	250.09	259.22	264.24
T_3: Fertigation of 20% RDF through WSF	12.21	53.04	141.21	246.52	252.89	259.17
T_4: Fertigation of 15% RDF through WSF	12.00	51.13	135.36	225.00	241.84	251.80
T_5: Fertigation of 25% RDF through CF + T_1	12.46	71.65	189.95	295.31	296.97	307.28
T_6: Fertigation of 25% RDF through CF + T_2	12.42	69.75	179.01	289.59	293.60	296.34
T_7: Fertigation of 25% RDF through CF + T_3	12.39	65.73	175.32	276.83	282.72	289.00
T_8: Fertigation of 25% RDF through CF + T_4	12.35	62.97	168.82	264.98	275.04	277.98
T_9: Fertigation of conventional fertilizers with 100 % RDF	12.68	74.72	203.97	322.12	325.21	329.39
S. Em. ±	0.41	1.83	5.22	9.72	7.11	8.30
C.D. (P = 0.05)	NS	5.50	15.64	29.13	21.33	24.88

NS: Non significant, DAS: Days after sowing, RDF: 150: 75: 75 N: P_2O_5: K_2O kg ha^{-1}, WSF: Water soluble fertilizer (19: 19: 19)

(45: 22.5: 22.5 kg ha^{-1}) through water soluble fertilizer along with 25 per cent RDF through conventional fertilizers applied in six equal splits (T_5) only at 60, 90, 120 DAS and at harvest (71.65, 189.95, 295.31 and 307.28 g plant^{-1}, respectively). Paired row sowing with fertigation of 15 per cent RDF (22.5: 11: 11 kg ha^{-1}) applied in six equal splits (T_4) recorded significantly lower total dry matter production. At 30 DAS, effect of different fertigation levels on total dry matter production was non significant.

Effect of drip fertigation with only water soluble fertilizers had significant effect on total dry matter production at all the growth stages except 30 DAS. However, paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) applied in six equal splits (T_1) recorded higher total dry matter production at 60, 90, 120, 150 DAS and at harvest (61.63, 155.20, 257.32, 265.40 and 269.31 g plant^{-1}, respectively) compared to other treatments.

Among different treatments involving either fertigation with only water soluble fertilizers or fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers, treatments included fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers recorded significantly higher total dry matter production compared to their respective fertigation with water soluble fertilizers only. Paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_5) recorded higher total dry matter production at 30, 60, 90, 120, 150 DAS and at harvest (12.46, 71.65, 189.95, 295.31, 296.97 and 303.32 g plant^{-1}, respectively) as compared to others.

4.2 Physiological observations

4.2.1 Leaf area index

The data pertaining to leaf area index are presented in Table 8. Significant differences were observed among treatments.

Leaf area index increased significantly in paired row sowing with fertigation of 100 per cent RDF (150:75:75 kg ha^{-1}) through conventional fertilizers applied in six equal splits (T_9) at 60, 90, 120, 150 DAS and at harvest (0.64, 1.86, 2.54, 2.22 and 0.58,

Table 8: Leaf area index of Bt cotton as influenced by fertigation levels with conventional and water soluble fertilizers

Treatment	Leaf area index					
	30 DAS	**60 DAS**	**90 DAS**	**120 DAS**	**150 DAS**	**At harvest**
T_1: Fertigation of 30% RDF through WSF	0.09	0.42	1.34	2.14	1.70	0.38
T_2: Fertigation of 25% RDF through WSF	0.09	0.42	1.13	2.13	1.49	0.36
T_3: Fertigation of 20% RDF through WSF	0.09	0.38	1.10	2.11	1.46	0.34
T_4: Fertigation of 15% RDF through WSF	0.08	0.33	1.02	2.04	1.38	0.29
T_5: Fertigation of 25% RDF through CF + T_1	0.11	0.55	1.66	2.31	2.02	0.50
T_6: Fertigation of 25% RDF through CF + T_2	0.10	0.51	1.59	2.23	1.95	0.47
T_7: Fertigation of 25% RDF through CF + T_3	0.10	0.46	1.52	2.16	1.88	0.42
T_8: Fertigation of 25% RDF through CF + T_4	0.10	0.44	1.45	2.14	1.81	0.40
T_9: Fertigation of conventional fertilizers with 100 % RDF	0.11	0.64	1.86	2.54	2.22	0.58
S. Em. ±	0.01	0.03	0.11	0.08	0.11	0.03
C.D. (P = 0.05)	NS	0.10	0.34	0.25	0.34	0.09

NS: Non significant, DAS: Days after sowing, RDF: 150: 75: 75 N: P_2O_5: K_2O kg ha^{-1}, WSF: Water soluble fertilizer (19: 19: 19)

respectively) and it was on par with paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_5) (0.55, 1.66, 2.31, 2.02 and 0.50, respectively). Significantly lower leaf area index was recorded in paired row sowing with fertigation of 15 per cent RDF (22.5: 11: 11 kg ha^{-1}) applied in six equal splits (T_4). At 30 DAS, effect of different fertigation levels on leaf area index was non significant.

Drip fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers had significant effect on leaf area index compared to respective fertigation with water soluble fertilizers only. Among the treatments involving fertigation with only water soluble fertilizers, paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) applied in six equal splits (T_1) recorded higher leaf area index at 60, 90, 120, 150 DAS and at harvest (0.09, 0.42, 1.34, 2.14, 1.70 and 0.38, respectively) compared to other treatments.

4.2.2 Leaf area duration

The data pertaining to leaf area duaration are presented in Table 9. Significant differences were observed among treatments.

Leaf area duaration increased significantly in paired row sowing with fertigation of 100 per cent RDF (150:75:75 kg ha^{-1}) through conventional fertilizers applied in six equal splits (T_9) at 30-60, 60-90, 90-120, 120-150 DAS and 150 DAS-at harvest (11.30, 37.50, 66.05, 71.45 and 42.05, respectively) and was on par with paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_5) (9.95, 33.15, 59.58, 64.97 and 37.75, respectively). Significantly lower leaf area duration was recorded in paired row sowing with fertigation of 15 per cent RDF (22.5: 11: 11 kg ha^{-1}) applied in six equal splits (T_4).

Drip fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers had significant effect on leaf area duration compared to respective fertigation with water soluble fertilizers only. Among the treatments involving fertigation with only water soluble fertilizers, paired row sowing with

Table 9: Leaf area duration of Bt cotton as influenced by fertigation levels with conventional and water soluble fertilizers

Treatment	Leaf area duration (days)				
	30-60 DAS	60-90 DAS	90-120 DAS	120-150 DAS	150 DAS- at harvest
T_1: Fertigation of 30% RDF through WSF	7.71	26.45	52.25	57.65	31.25
T_2: Fertigation of 25% RDF through WSF	7.62	23.30	49.00	54.40	27.75
T_3: Fertigation of 20% RDF through WSF	7.12	22.30	48.15	53.55	27.10
T_4: Fertigation of 15% RDF through WSF	6.15	20.15	45.85	51.25	24.95
T_5: Fertigation of 25% RDF through CF + T_1	9.95	33.15	59.58	64.98	37.75
T_6: Fertigation of 25% RDF through CF + T_2	9.10	31.40	57.30	62.70	36.20
T_7: Fertigation of 25% RDF through CF + T_3	8.40	29.75	55.15	60.55	34.55
T_8: Fertigation of 25% RDF through CF + T_4	8.11	28.38	53.93	59.33	33.18
T_9: Fertigation of conventional fertilizers with 100 % RDF	11.30	37.50	66.05	71.45	42.05
S. Em. ±	0.52	1.84	2.16	2.16	1.82
C.D. (P = 0.05)	1.56	5.52	6.48	6.48	5.47

DAS: Days after sowing, RDF: 150: 75: 75 N: P_2O_5: K_2O kg ha^{-1}, WSF: Water soluble fertilizer (19: 19: 19)

fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) applied in six equal splits (T_1) recorded higher leaf area duration at 30-60, 60-90, 90-120, 120-150 DAS and 150 DAS-at harvest (7.71, 26.45, 52.25, 57.65 and 31.25, respectively) compared to other treatments.

4.2.3 Chlorophyll content in leaf

The data pertaining to SPAD value are presented in Table 10. Significant differences were observed among treatments.

SPAD value increased significantly in paired row sowing with fertigation of 100 per cent RDF (150:75:75 kg ha^{-1}) through conventional fertilizers applied in six equal splits (T_9) at 30, 60, 90, 120, 150 DAS and at harvest (35.77, 41.10, 42.20, 47.63, 37.71 and 29.48, respectively) and was on par with paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_5) (33.83, 38.93, 39.93, 43.70, 34.91 and 23.81, respectively) and paired row sowing with fertigation of 25 per cent RDF (37.5: 19: 19 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_6) at 30, 60 and 90 DAS (33.20, 38.40, 39.30 and 39.30, respectively). Significantly lower SPAD value was recorded in paired row sowing with fertigation of 15 per cent RDF (22.5: 11: 11 kg ha^{-1}) applied in six equal splits (T_4).

Drip fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers had significant effect on SPAD value compared to respective fertigation with water soluble fertilizers only. Among the treatments involving fertigation with only water soluble fertilizers, paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) applied in six equal splits (T_1) recorded higher SPAD value at 30, 60, 90, 120, 150 DAS and at harvest (31.13, 36.67, 37.23, 40.40, 30.04 and 21.18, respectively) compared to other treatments.

4.2.4 Leaf reddening (Visual observation)

The data pertaining to leaf reddening are presented in Table 11. Significant differences were observed among treatments.

Table 10: Chlorophyll content in leaf of Bt cotton as influenced by fertigation levels with conventional and water soluble fertilizers

Treatment	Chlorophyll content in leaf (SPAD value)					
	30 DAS	**60 DAS**	**90 DAS**	**120 DAS**	**150 DAS**	**At harvest**
T_1: Fertigation of 30% RDF through WSF	31.13	36.67	37.23	40.40	30.04	21.18
T_2: Fertigation of 25% RDF through WSF	30.40	35.93	36.50	39.63	29.74	20.01
T_3: Fertigation of 20% RDF through WSF	29.96	35.60	36.13	38.70	28.21	19.65
T_4: Fertigation of 15% RDF through WSF	29.50	34.03	35.60	38.53	26.41	18.18
T_5: Fertigation of 25% RDF through CF + T_1	33.83	38.93	39.93	43.70	34.91	23.81
T_6: Fertigation of 25% RDF through CF + T_2	33.20	38.40	39.30	42.47	32.24	22.85
T_7: Fertigation of 25% RDF through CF + T_3	31.63	37.69	37.73	42.40	32.04	21.81
T_8: Fertigation of 25% RDF through CF + T_4	31.37	36.73	37.47	41.57	31.08	21.68
T_9: Fertigation of conventional fertilizers with 100 % RDF	35.77	41.10	42.20	47.63	37.71	29.48
S. Em. ±	1.24	1.17	1.26	1.48	1.71	1.92
C.D. (P = 0.05)	3.72	3.50	3.77	4.45	5.12	5.76

DAS: Days after sowing, RDF: 150: 75: 75 N: P_2O_5: K_2O kg ha^{-1}, WSF: Water soluble fertilizer (19: 19: 19)

Table 11: Leaf reddening of Bt cotton as influenced by fertigation levels with conventional and water soluble fertilizers

Treatment	Leaf reddening	
	90 DAS	120 DAS
T_1: Fertigation of 30% RDF through WSF	5.00	7.13
T_2: Fertigation of 25% RDF through WSF	5.53	7.40
T_3: Fertigation of 20% RDF through WSF	5.67	7.93
T_4: Fertigation of 15% RDF through WSF	6.07	8.47
T_5: Fertigation of 25% RDF through CF + T_1	3.40	6.20
T_6: Fertigation of 25% RDF through CF + T_2	3.80	6.47
T_7: Fertigation of 25% RDF through CF + T_3	4.33	6.73
T_8: Fertigation of 25% RDF through CF + T_4	4.60	7.00
T_9: Fertigation of conventional fertilizers with 100 % RDF	2.40	5.13
S. Em. ±	0.17	0.35
C.D. (P = 0.05)	0.52	1.06

DAS: Days after sowing, RDF: 150: 75: 75 N: P_2O_5: K_2O kg ha^{-1}, WSF: Water soluble fertilizer (19: 19: 19)

Leaf reddening decreased significantly in paired row sowing with fertigation of 100 per cent RDF (150:75:75 kg ha^{-1}) through conventional fertilizers applied in six equal splits (T_9) reddening at 90 and 120DAS (2.40 and 5.13, respectively) over other treatments. Significantly higher leaf reddening was recorded in paired row sowing with fertigation of 15 per cent RDF (22.5: 11: 11 kg ha^{-1}) applied in six equal splits (T_4).

Drip fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers had significant effect on leaf reddening compared to respective fertigation with water soluble fertilizers only. Among the treatments involving fertigation with only water soluble fertilizers, paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) applied in six equal splits (T_1) recorded lower leaf reddening at 90 and 120 DAS (5.00 and 7.13, respectively) compared to other treatments.

4.3 Yield and yield components

4.3.1 Number of monopodia per plant

The data on number of monopodia per plant are presented in Table 12. The results indicated no significant differences among the treatments.

The number of monopodia per plant was influenced with each levels of fertigation, but not differed significantly. Influence of drip fertigation with only water soluble fertilizers had no significant effect on number of monopodia per plant. Among different treatments involving either fertigation with only water soluble fertilizers or fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers had no significant effect on number of monopodia per plant.

4.3.2 Number of sympodia per plant

The data on number of sympodia per plant are presented in Table 13. The results indicated no significant differences among the treatments.

The number of sympodia per plant was influenced with each levels of fertigation, but not differed significantly. Influence of drip fertigation with only water soluble fertilizers had no significant effect on number of sympodia per plant. Among

Table 12: Number of monopodia per plant of Bt cotton as influenced by fertigation levels with water soluble and conventional fertilizers

Treatment	Number of monopodia per plant				
	60 DAS	90 DAS	120 DAS	150 DAS	At harvest
T_1: Fertigation of 30% RDF through WSF	2.27	2.80	2.80	2.80	2.80
T_2: Fertigation of 25% RDF through WSF	2.20	2.73	2.73	2.73	2.73
T_3: Fertigation of 20% RDF through WSF	2.13	2.67	2.67	2.67	2.67
T_4: Fertigation of 15% RDF through WSF	2.00	2.60	2.60	2.60	2.60
T_5: Fertigation of 25% RDF through CF + T_1	2.40	3.00	3.00	3.00	3.00
T_6: Fertigation of 25% RDF through CF + T_2	2.40	2.93	2.93	2.93	2.93
T_7: Fertigation of 25% RDF through CF + T_3	2.33	2.87	2.87	2.87	2.87
T_8: Fertigation of 25% RDF through CF + T_4	2.33	2.80	2.80	2.80	2.80
T_9: Fertigation of conventional fertilizers with 100 % RDF	2.53	3.20	3.20	3.20	3.20
S. Em. ±	0.14	0.20	0.20	0.20	0.20
C.D. (P = 0.05)	NS	NS	NS	NS	NS

NS: Non significant, DAS: Days after sowing, RDF: 150: 75: 75 N: P_2O_5: K_2O kg ha^{-1}, WSF: Water soluble fertilizer (19: 19: 19)

different treatments involving either fertigation with only water soluble fertilizers or fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers had no significant effect on number of sympodia per plant.

4.3.3 Number of good opened bolls per plant

The data on number of good opened bolls per plant are presented in Table 14. The results indicated significant differences among treatments.

Significantly higher number of good opened bolls per plant was recorded in paired row sowing with fertigation of 100 per cent RDF (150:75:75 kg ha^{-1}) through conventional fertilizers applied in six equal splits (T_9) (52.47) and it was on par with paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_5) (47.93). Significantly lower number of good opened bolls per plant was recorded in paired row sowing with fertigation of 15 per cent RDF (22.5: 11: 11 kg ha^{-1}) applied in six equal splits (T_4) (36.00).

Drip fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers had significant effect on number of good opened bolls per plant compared to respective fertigation with water soluble fertilizers only. Among the treatments involving fertigation with only water soluble fertilizers, paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) applied in six equal splits (T_1) recorded higher number of good opened bolls per plant (41.33) compared to other treatments.

4.3.4 Number of bad opened bolls per plant

The data on number of bad opened bolls per plant are presented in Table 14. The results indicated significant differences among treatments.

Significantly lower number of bad opened bolls per plant was recorded in paired row sowing with fertigation of 100 per cent RDF (150:75:75 kg ha^{-1}) through conventional fertilizers applied in six equal splits (T_9) (1.93) and it was on par with paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in

Table 13: Number of sympodia per plant of Bt cotton as influenced by fertigation levels with conventional and water soluble fertilizers

Treatment	Number of sympodia per plant				
	60 DAS	90 DAS	120 DAS	150 DAS	At harvest
T_1: Fertigation of 30% RDF through WSF	7.80	17.87	19.27	19.27	19.27
T_2: Fertigation of 25% RDF through WSF	7.73	17.73	19.00	19.00	19.00
T_3: Fertigation of 20% RDF through WSF	7.60	17.33	18.67	18.67	18.67
T_4: Fertigation of 15% RDF through WSF	7.53	16.80	18.53	18.53	18.53
T_5: Fertigation of 25% RDF through CF + T_1	8.13	19.07	20.53	20.53	20.53
T_6: Fertigation of 25% RDF through CF + T_2	8.00	18.73	20.27	20.27	20.27
T_7: Fertigation of 25% RDF through CF + T_3	7.87	18.53	19.53	19.53	19.53
T_8: Fertigation of 25% RDF through CF + T_4	7.87	18.13	19.27	19.27	19.27
T_9: Fertigation of conventional fertilizers with 100 % RDF	8.13	19.73	20.80	20.80	20.80
S. Em. ±	0.24	0.85	0.78	0.78	0.78
C.D. (P = 0.05)	NS	NS	NS	NS	NS

NS: Non significant, DAS: Days after sowing, RDF: 150: 75: 75 N: P_2O_5: K_2O kg ha^{-1}, WSF: Water soluble fertilizer (19: 19: 19)

six equal splits (T_5) (2.13) and paired row sowing with fertigation of 25 per cent RDF (37.5: 19: 19 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_6) (2.27). Paired row sowing with fertigation of 20 per cent RDF (30: 15: 15kg ha^{-1}) applied in six equal splits (T_3) and paired row sowing with fertigation of 15 per cent RDF (22.5: 11: 11 kg ha^{-1}) applied in six equal splits (T_4) recorded significantly higher number of bad opened bolls per plant (3.20 each).

Drip fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers had significant effect on number of bad opened bolls per plant compared to respective fertigation with water soluble fertilizers only. Among the treatments involving fertigation with only water soluble fertilizers, paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) applied in six equal splits (T_1) recorded lower number of bad opened bolls per plant (2.73) compared to other treatments.

4.3.5 Total bolls per plant

The data pertaining on total bolls per plant are presented in Table 14. Significant differences were observed among treatments.

Total bolls per plant increased significantly in paired row sowing with fertigation of 100 per cent RDF (150:75:75 kg ha^{-1}) through conventional fertilizers applied in six equal splits (T_9) (54.40) and it was on par with paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_5) (50.07) and paired row sowing with fertigation of 25 per cent RDF (37.5: 19: 19 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_6) (48.13). Significantly lower total bolls per plant was recorded in paired row sowing with fertigation of 15 per cent RDF (22.5: 11: 11 kg ha^{-1}) applied in six equal splits (T_4) (39.20).

Drip fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers had significant effect on total bolls per plant compared to respective fertigation with water soluble fertilizers only. Among the treatments

Table 14: Good opened bolls, bad opened bolls and total number of bolls per plant of Bt cotton as influenced by fertigation levels with conventional and water soluble fertilizers

Treatment	Good opened bolls plant^{-1} (GOB)	Bad opened bolls plant^{-1} (BOB)	Total bolls plant^{-1}
T_1: Fertigation of 30% RDF through WSF	41.33	2.73	44.07
T_2: Fertigation of 25% RDF through WSF	39.67	3.07	42.73
T_3: Fertigation of 20% RDF through WSF	39.20	3.20	42.40
T_4: Fertigation of 15% RDF through WSF	36.00	3.20	39.20
T_5: Fertigation of 25% RDF through CF + T_1	47.93	2.13	50.07
T_6: Fertigation of 25% RDF through CF + T_2	45.87	2.27	48.13
T_7: Fertigation of 25% RDF through CF + T_3	43.93	2.33	46.27
T_8: Fertigation of 25% RDF through CF + T_4	42.00	2.60	44.60
T_9: Fertigation of conventional fertilizers with 100 % RDF	52.47	1.93	54.40
S. Em. ±	2.10	0.19	2.16
C.D. (P = 0.05)	6.31	0.57	6.49

DAS: Days after sowing, RDF: 150: 75: 75 N: P_2O_5: K_2O kg ha^{-1}, WSF: Water soluble fertilizer (19: 19: 19)

involving fertigation with only water soluble fertilizers, paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) applied in six equal splits (T_1) recorded higher total bolls per plant (44.07) compared to other treatments.

4.3.6 Boll weight

. Data pertaining to boll weight as influenced by different fertigation levels with conventional and water soluble fertilizers are presented in Table 15. The boll weight not differed significantly among the treatments.

The boll weight was influenced with each levels of fertigation, but not differed significantly. Influence of drip fertigation with only water soluble fertilizers had no significant effect on number of sympodia per plant. Among different treatments involving either fertigation with only water soluble fertilizers or fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers had no significant effect on boll weight.

4.3.7 Seed cotton yield per plant

The data on seed cotton yield per plant are presented in Table 15. The seed cotton yield per plant differed significantly among the treatments.

Paired row sowing with fertigation of 100 per cent RDF (150:75:75 kg ha^{-1}) through conventional fertilizers applied in six equal splits (T_9) recorded significantly higher seed cotton yield per plant (275.20 g plant^{-1}) and was on par with paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_5) (251.43 g plant^{-1}) and paired row sowing with fertigation of 25 per cent RDF (37.5: 19: 19 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_6) (243.27 g plant^{-1}). Paired row sowing with fertigation of 15 per cent RDF (22.5: 11: 11 kg ha^{-1}) applied in six equal splits (T_4) recorded significantly lower seed cotton yield per plant (196.40 g plant^{-1}).

Drip fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers had significant effect on seed cotton yield per plant compared to respective fertigation with water soluble fertilizers only. Among the treatments

Table 15: Boll weight, seed cotton yield per plant, seed cotton yield and stalk yield per hectare of Bt cotton as influenced by fertigation levels with conventional and water soluble fertilizers

Treatment	Boll wt (g)	Yield per plant (g)	Seed cotton yield (kg ha^{-1})	Stalk yield (kg ha^{-1})	Harvest index
T_1: Fertigation of 30% RDF through WSF	6.03	207.33	3,089	4,313	0.42
T_2: Fertigation of 25% RDF through WSF	6.03	205.20	2,890	4,117	0.41
T_3: Fertigation of 20% RDF through WSF	6.02	198.80	2,780	4,105	0.40
T_4: Fertigation of 15% RDF through WSF	5.98	196.40	2,638	4,057	0.39
T_5: Fertigation of 25% RDF through CF + T_1	6.16	251.43	3,894	5,337	0.42
T_6: Fertigation of 25% RDF through CF + T_2	6.12	243.27	3,783	5,201	0.42
T_7: Fertigation of 25% RDF through CF + T_3	6.11	214.93	3,335	4,538	0.42
T_8: Fertigation of 25% RDF through CF + T_4	6.09	211.47	3,168	4,361	0.42
T_9: Fertigation of conventional fertilizers with 100 % RDF	6.22	275.20	4,000	5,417	0.43
S. Em. ±	0.18	12.59	135	152	0.02
C.D. (P = 0.05)	NS	37.75	404	455	NS

NS: Non significant, DAS: Days after sowing, RDF: 150: 75: 75 N: P_2O_5: K_2O kg ha^{-1}, WSF: Water soluble fertilizer (19: 19: 19)

involving fertigation with only water soluble fertilizers, paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) applied in six equal splits (T_1) recorded higher seed cotton yield per plant (207.33 g $plant^{-1}$) compared to other treatments.

4.3.8 Seed cotton yield per hectare

The data on seed cotton yield are presented in Table 15. The seed cotton yield differed significantly among the treatments.

Paired row sowing with fertigation of 100 per cent RDF (150:75:75 kg ha^{-1}) through conventional fertilizers applied in six equal splits (T_9) recorded significantly higher seed cotton yield (4,000 kg ha^{-1}) and was on par with paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_5) (3,894 kg ha^{-1}) and paired row sowing with fertigation of 25 per cent RDF (37.5: 19: 19 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_6) (3,783 kg ha^{-1}). Paired row sowing with fertigation of 15 per cent RDF (22.5: 11: 11 kg ha^{-1}) applied in six equal splits (T_4) recorded significantly lower seed cotton yield (2,638 kg ha^{-1}).

Drip fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers had significant effect on seed cotton yield compared to respective fertigation with water soluble fertilizers only. Among the treatments involving fertigation with only water soluble fertilizers, paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) applied in six equal splits (T_1) recorded higher seed cotton yield (3,089 kg ha^{-1}) compared to other treatments.

4.3.9 Cotton stalk yield per hectare

The data on cotton stalk yield are presented in Table 15. The cotton stalk yield differed significantly among the treatments.

Paired row sowing with fertigation of 100 per cent RDF (150:75:75 kg ha^{-1}) through conventional fertilizers applied in six equal splits (T_9) recorded significantly higher cotton stalk yield (5,417 kg ha^{-1}) and was on par with paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_5) (5,337 kg ha^{-1}) and paired row sowing with fertigation of 25 per cent RDF (37.5: 19: 19 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_6) (5,201 kg ha^{-1}). Paired row sowing with fertigation of 15 per cent RDF (22.5: 11: 11 kg ha^{-1}) applied in six equal splits (T_4) recorded significantly lower seed cotton yield (4,057 kg ha^{-1}).

Drip fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers had significant effect on cotton stalk yield compared to respective fertigation with water soluble fertilizers only. Among the treatments involving fertigation with only water soluble fertilizers, paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) applied in six equal splits (T_1) recorded higher seed cotton yield (4,313 kg ha^{-1}) compared to other treatments

4.3.10 Harvest index

The data on harvest index are presented in Table 15. The results indicated no significant differences among the treatments.

Harvest index was influenced with each levels of fertigation, but not differed significantly. Influence of drip fertigation with only water soluble fertilizers had no significant effect on harvest index. Among different treatments involving either fertigation with only water soluble fertilizers or fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers had no significant effect on harvest index.

4.4 Quality parameters

4.4.1 2.5 per cent span length

Data on fibre length as influenced by different fertigation levels with conventional and water soluble fertilizers are presented in Table 16.

The fibre length was influenced by each levels of fertigation, but not differed significantly. Influence of drip fertigation with only water soluble fertilizers had no significant effect on fibre length.

Among different treatments involving either fertigation with only water soluble fertilizers or fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers had no significant effect on fibre length.

4.4.2 Fibre strength

Data on fibre strength as influenced by different fertigation levels with conventional and water soluble fertilizers are presented in Table 16.

The data indicated that fertigation with water soluble fertilizers had significant effect on fibre strength than that of fertigation with conventional fertilizers. Among different treatments, paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) in six equal splits (T_1) recorded higher fibre strength (28.03 g tex^{-1}) as compared to other treatments. Paired row sowing with fertigation of 15 per cent RDF (22.5: 11: 11 kg ha^{-1}) applied in six equal splits (T_4) recorded significantly lower fibre strength (23.23 g tex^{-1})

4.4.3 Uniformity ratio

Data on fibre uniformity ratio as influenced by different fertigation levels with conventional and water soluble fertilizers are presented in Table 16.

The uniformity ratio was influenced by each levels of fertigation, but not differed significantly. Influence of drip fertigation with only water soluble fertilizers had no significant effect on uniformity ratio.

Among different treatments involving either fertigation with only water soluble fertilizers or fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers had no significant effect on uniformity ratio.

Table 16: Quality parameters of Bt cotton as influenced by fertigation levels with conventional and water soluble fertilizers

Treatment	Fibre length (mm)	Fibre strength (g/ tex)	Micronaire value (µg/inch)	Uniformity ratio (%)	Fibre elongation (%)
T_1: Fertigation of 30% RDF through WSF	27.00	28.03	3.93	82.33	4.77
T_2: Fertigation of 25% RDF through WSF	25.97	27.17	4.05	81.43	4.87
T_3: Fertigation of 20% RDF through WSF	26.40	26.40	4.04	80.80	5.23
T_4: Fertigation of 15% RDF through WSF	24.93	23.23	3.86	80.50	5.63
T_5: Fertigation of 25% RDF through CF + T_1	26.53	27.07	3.92	81.40	4.90
T_6: Fertigation of 25% RDF through CF + T_2	26.33	26.47	4.09	81.43	4.97
T_7: Fertigation of 25% RDF through CF + T_3	26.73	27.17	4.09	79.00	4.90
T_8: Fertigation of 25% RDF through CF + T_4	26.80	26.53	3.99	81.20	5.00
T_9: Fertigation of conventional fertilizers with 100 % RDF	24.93	26.53	4.08	81.93	4.90
S. Em. $\pm$	0.65	0.63	0.07	1.19	0.21
C.D. (P = 0.05)	NS	1.89	NS	NS	NS

NS: Non significant, DAS: Days after sowing, RDF: 150: 75: 75 N: P_2O_5: K_2O kg ha^{-1}, WSF: Water soluble fertilizer (19: 19: 19)

4.4.4 Micronaire value

Data on micronaire value as influenced by different fertigation levels with conventional and water soluble fertilizers are presented in Table 16.

The micronaire value was influenced by each levels of fertigation, but not differed significantly. Influence of drip fertigation with only water soluble fertilizers had no significant effect on micronaire value.

Among different treatments involving either fertigation with only water soluble fertilizers or fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers had no significant effect on micronaire value.

4.4.5 Fibre elongation

Data on fibre elongation as influenced by different fertigation levels with conventional and water soluble fertilizers are presented in Table 16.

The fibre elongation was influenced by each levels of fertigation, but not differed significantly. Influence of drip fertigation with only water soluble fertilizers had no significant effect on fibre elongation.

Among different treatments involving either fertigation with only water soluble fertilizers or fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers had no significant effect on fibre elongation.

4.4.6 Seed index

The data on seed index are presented in Table 17. The results indicated no significant differences among the treatments.

The seed index was influenced with each levels of fertigation, but not differed significantly. Influence of drip fertigation with only water soluble fertilizers had no significant effect on seed index. Among different treatments involving either fertigation with only water soluble fertilizers or fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers had no significant effect on seed index.

Table 17: Seed index, ginning out turn and lint index of Bt cotton as influenced by fertigation levels with conventional and water soluble fertilizers

Treatment	Seed index (g)	Ginning out turn (%)	Lint index (%)
T_1: Fertigation of 30% RDF through WSF	9.64	34.00	4.99
T_2: Fertigation of 25% RDF through WSF	9.61	33.67	4.87
T_3: Fertigation of 20% RDF through WSF	9.49	33.56	4.84
T_4: Fertigation of 15% RDF through WSF	9.35	33.44	4.71
T_5: Fertigation of 25% RDF through CF + T_1	9.89	34.33	5.17
T_6: Fertigation of 25% RDF through CF + T_2	9.84	34.33	5.15
T_7: Fertigation of 25% RDF through CF + T_3	9.77	34.22	5.14
T_8: Fertigation of 25% RDF through CF + T_4	9.64	34.11	5.04
T_9: Fertigation of conventional fertilizers with 100 % RDF	10.02	34.67	5.39
S. Em. ±	0.33	1.96	0.50
C.D. (P = 0.05)	NS	NS	NS

NS: Non significant, DAS: Days after sowing, RDF: 150: 75: 75 N: P_2O_5: K_2O kg ha^{-1}, WSF: Water soluble fertilizer (19: 19: 19)

4.4.7 Ginning out turn

The data on ginning out turn are presented in Table 17. The results indicated no significant differences among the treatments.

The ginning out turn was influenced with each levels of fertigation, but not differed significantly. Influence of drip fertigation with only water soluble fertilizers had no significant effect on ginning out turn. Among different treatments involving either fertigation with only water soluble fertilizers or fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers had no significant effect on ginning out turn.

4.4.8 Lint index

The data on lint index are presented in Table 17. The results indicated no significant differences among the treatments.

The lint index was influenced with each levels of fertigation, but not differed significantly. Influence of drip fertigation with only water soluble fertilizers had no significant effect on lint index. Among different treatments involving either fertigation with only water soluble fertilizers or fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers had no significant effect on lint index.

4.5 Plant analysis

4.5.1 Nitrogen content in stem

The data on nitrogen content in stem are presented in Table 18. Nitrogen content in stem differed significantly due to different fertigation levels with conventional and water soluble fertilizers.

Influence of different fertigation levels in paired row sowing on nitrogen content in stem was significant at all the growth stages. The data indicated that paired row sowing with fertigation of 100 per cent RDF (150:75:75 kg ha^{-1}) through conventional fertilizers applied in six equal splits (T_9) recorded significantly higher nitrogen content in stem at 60, 90, 120, 150 DAS and at harvest (2.03, 2.54, 1.66, 1.56 and 1.32 per cent,

Table 18: Nitrogen content in stem of Bt cotton as influenced by fertigation levels with conventional and water soluble fertilizers

Treatment	Nitrogen content in stem (%)				
	60 DAS	90 DAS	120 DAS	150 DAS	At harvest
T_1: Fertigation of 30% RDF through WSF	1.50	1.85	1.29	1.02	0.89
T_2: Fertigation of 25% RDF through WSF	1.47	1.79	1.26	0.97	0.82
T_3: Fertigation of 20% RDF through WSF	1.42	1.66	1.22	0.93	0.79
T_4: Fertigation of 15% RDF through WSF	1.38	1.59	1.07	0.75	0.65
T_5: Fertigation of 25% RDF through CF + T_1	1.95	2.14	1.56	1.51	1.22
T_6: Fertigation of 25% RDF through CF + T_2	1.65	2.06	1.50	1.31	1.14
T_7: Fertigation of 25% RDF through CF + T_3	1.61	2.00	1.39	1.26	1.03
T_8: Fertigation of 25% RDF through CF + T_4	1.55	1.91	1.35	1.00	0.90
T_9: Fertigation of conventional fertilizers with 100 % RDF	2.03	2.54	1.66	1.56	1.32
S. Em. ±	0.07	0.09	0.05	0.04	0.07
C.D. (P = 0.05)	0.20	0.27	0.15	0.13	0.20

DAS: Days after sowing, RDF: 150: 75: 75 N: P_2O_5: K_2O kg ha^{-1}, WSF: Water soluble fertilizer (19: 19: 19)

respectively) over other treatments. However, it was on par with paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_5) at 60, 120, 150 DAS and at harvest (1.95, 1.56, 1.51 and 1.22 per cent, respectively). Paired row sowing with fertigation of 15 per cent RDF (22.5: 11: 11 kg ha^{-1}) applied in six equal splits (T_4) recorded significantly lower nitrogen content in stem at all growth stages.

Effect of drip fertigation with only water soluble fertilizers had significant effect on nitrogen content in stem at all the growth stages. Among treatments involving fertigation with only water soluble fertilizers, paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) applied in six equal splits (T_1) recorded higher nitrogen content in stem at 60, 90, 120, 150 DAS and at harvest (1.50, 1.85, 1.29, 1.02 and 0.89 per cent, respectively) as compared to other treatments.

Among different treatments involving either fertigation with only water soluble fertilizers or fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers, fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers had significant effect on nitrogen content in stem compared to respective fertigation with water soluble fertilizers only. Paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_5) recorded higher nitrogen content in stem at 60, 90, 120, 150 DAS and at harvest (1.95, 2.14, 1.56, 1.51 and 1.22 per cent, respectively) compared to others. However, it was on par with paired row sowing with fertigation of 25 per cent RDF (37.5: 19: 19 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_6) at 90, 120 DAS and at harvest (2.06, 1.50 and 1.14 per cent, respectively).

4.5.2 Nitrogen content in leaf

The data on nitrogen content in leaf are presented in Table 19. Nitrogen content in leaf differed significantly due to different fertigation levels with conventional and water soluble fertilizers.

Table 19: Nitrogen content in leaf of Bt cotton as influenced by fertigation levels with conventional and water soluble fertilizers

Treatment	Nitrogen content in leaf (%)				
	60 DAS	90 DAS	120 DAS	150 DAS	At harvest
T_1: Fertigation of 30% RDF through WSF	2.60	3.51	2.38	1.95	1.49
T_2: Fertigation of 25% RDF through WSF	2.56	3.50	2.28	1.89	1.44
T_3: Fertigation of 20% RDF through WSF	2.53	3.49	2.07	1.75	1.39
T_4: Fertigation of 15% RDF through WSF	2.45	3.45	1.83	1.58	1.20
T_5: Fertigation of 25% RDF through CF + T_1	2.93	3.92	2.76	2.48	1.80
T_6: Fertigation of 25% RDF through CF + T_2	2.86	3.81	2.64	2.26	1.65
T_7: Fertigation of 25% RDF through CF + T_3	2.67	3.57	2.55	2.01	1.58
T_8: Fertigation of 25% RDF through CF + T_4	2.63	3.56	2.47	1.97	1.52
T_9: Fertigation of conventional fertilizers with 100 % RDF	3.74	4.92	3.51	3.31	2.56
S. Em. ±	0.12	0.13	0.12	0.10	0.10
C.D. (P = 0.05)	0.37	0.39	0.35	0.31	0.30

DAS: Days after sowing, RDF: 150: 75: 75 N: P_2O_5: K_2O kg ha^{-1}, WSF: Water soluble fertilizer (19: 19: 19)

Influence of different fertigation levels in paired row sowing on nitrogen content in stem was significant at all the growth stages. The data indicated that paired row sowing with fertigation of 100 per cent RDF (150:75:75 kg ha^{-1}) through conventional fertilizers applied in six equal splits (T_9) recorded significantly higher nitrogen content in leaf at 60, 90, 120, 150 DAS and at harvest (3.74, 4.92, 3.51, 3.31 and 2.56 per cent, respectively) over other treatments. Paired row sowing with fertigation of 15 per cent RDF (22.5: 11: 11 kg ha^{-1}) applied in six equal splits (T_4) recorded significantly lower nitrogen content in leaf at all growth stages.

Effect of drip fertigation with only water soluble fertilizers had significant effect on nitrogen content in leaf at all the growth stages. However, paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) applied in six equal splits (T_1) recorded higher nitrogen content in leaf at 60, 90, 120, 150 DAS and at harvest (2.60, 3.51, 2.38, 1.95 and 1.49 per cent, respectively).

Among different treatments involving either fertigation with only water soluble fertilizers or fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers, fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers had significant effect on nitrogen content in leaf compared to respective fertigation with water soluble fertilizers only. Paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_5) recorded higher nitrogen content in leaf at 60, 90, 120, 150 DAS and at harvest (2.93, 3.92, 2.76, 2.48 and 1.80 per cent, respectively) as compared to others.

4.5.3 Nitrogen content in reproductive parts

The data on nitrogen content in reproductive parts are presented in Table 20. Nitrogen content in reproductive parts differed significantly due to different fertigation levels with conventional and water soluble fertilizers.

Influence of different fertigation levels in paired row sowing on nitrogen content in reproductive parts was significant at all the growth stages. The data indicated that paired row sowing with fertigation of 100 per cent RDF (150:75:75 kg ha^{-1}) through conventional fertilizers applied in six equal splits (T_9) recorded significantly higher

Table 20: Nitrogen content in reproductive parts of Bt cotton as influenced by fertigation levels with conventional and water soluble fertilizers

Treatment	Nitrogen content in reproductive parts (%)				
	60 DAS	**90 DAS**	**120 DAS**	**150 DAS**	**At harvest**
T_1: Fertigation of 30% RDF through WSF	2.91	3.41	2.76	2.20	1.23
T_2: Fertigation of 25% RDF through WSF	2.76	3.34	2.67	2.17	1.15
T_3: Fertigation of 20% RDF through WSF	2.67	3.14	2.57	2.09	1.05
T_4: Fertigation of 15% RDF through WSF	2.62	2.95	2.00	1.45	0.93
T_5: Fertigation of 25% RDF through CF + T_1	3.71	3.88	2.87	2.70	1.56
T_6: Fertigation of 25% RDF through CF + T_2	3.54	3.71	2.81	2.47	1.40
T_7: Fertigation of 25% RDF through CF + T_3	3.32	3.69	2.81	2.33	1.31
T_8: Fertigation of 25% RDF through CF + T_4	2.99	3.51	2.73	2.26	1.27
T_9: Fertigation of conventional fertilizers with 100 % RDF	3.89	4.35	3.18	2.87	1.75
S. Em. ±	0.10	0.12	0.07	0.10	0.05
C.D. (P = 0.05)	0.30	0.36	0.20	0.30	0.14

DAS: Days after sowing, RDF: 150: 75: 75 N: P_2O_5: K_2O kg ha^{-1}, WSF: Water soluble fertilizer (19: 19: 19)

nitrogen content in in reproductive parts at 60, 90, 120, 150 DAS and at harvest (3.89, 4.35, 3.18, 2.87 and 1.75 per cent, respectively) over other treatments and was on par with paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_5) at 60 and 150 DAS (3.71 and 2.70 per cent, respectively). Paired row sowing with fertigation of 15 per cent RDF (22.5: 11: 11 kg ha^{-1}) applied in six equal splits (T_4) recorded significantly lower nitrogen content in reproductive parts at all growth stages.

Effect of drip fertigation with only water soluble fertilizers had significant effect on nitrogen content in reproductive parts at all the growth stages. However, paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) applied in six equal splits (T_1) recorded higher nitrogen content in reproductive parts at 60, 90, 120, 150 DAS and at harvest (2.91, 3.41, 2.76, 2.20 and 1.23 per cent, respectively) compared to other treatments.

Among different treatments involving either fertigation with only water soluble fertilizers or fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers, fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers had significant effect on nitrogen content in reproductive parts compared to respective fertigation with water soluble fertilizers only. Paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_5) recorded higher nitrogen content in reproductive parts at 60, 90, 120, 150 DAS and at harvest (3.71, 3.88, 2.87, 2.70 and 1.56 per cent, respectively) compared to others. However, it was on par with paired row sowing with fertigation of 25 per cent RDF (37.5: 19: 19 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_6) (3.54, 3.71, 2.81, 2.47 and 1.40 per cent, respectively).

4.5.4 Phosphorus content in stem

The data on phosphorus content in stem are presented in Table 21. Phosphorus content in stem differed significantly due to different fertigation levels with conventional and water soluble fertilizers.

Table 21: Phosphorus content in stem of Bt cotton as influenced by fertigation levels with conventional and water soluble fertilizers

Treatment	Phosphorus content in stem (%)				
	60 DAS	90 DAS	120 DAS	150 DAS	At harvest
T_1: Fertigation of 30% RDF through WSF	0.35	0.41	0.39	0.32	0.23
T_2: Fertigation of 25% RDF through WSF	0.34	0.39	0.35	0.29	0.20
T_3: Fertigation of 20% RDF through WSF	0.32	0.38	0.35	0.27	0.19
T_4: Fertigation of 15% RDF through WSF	0.29	0.33	0.31	0.23	0.15
T_5: Fertigation of 25% RDF through CF + T_1	0.40	0.45	0.44	0.37	0.28
T_6: Fertigation of 25% RDF through CF + T_2	0.38	0.45	0.43	0.35	0.26
T_7: Fertigation of 25% RDF through CF + T_3	0.37	0.44	0.41	0.33	0.25
T_8: Fertigation of 25% RDF through CF + T_4	0.36	0.44	0.40	0.33	0.24
T_9: Fertigation of conventional fertilizers with 100 % RDF	0.39	0.48	0.46	0.40	0.31
S. Em. ±	0.03	0.03	0.02	0.02	0.02
C.D. (P = 0.05)	NS	0.08	0.07	0.07	0.06

NS: Non significant, DAS: Days after sowing, RDF: 150: 75: 75 N: P_2O_5: K_2O kg ha^{-1}, WSF: Water soluble fertilizer (19: 19: 19)

Influence of different fertigation levels in paired row sowing on phosphorus content in stem was significant at all the growth stages except at 60 DAS. The data indicated that paired row sowing with fertigation of 100 per cent RDF (150:75:75 kg ha^{-1}) through conventional fertilizers applied in six equal splits (T_9) recorded significantly higher phosphorus content in stem at 90, 120, 150 DAS and at harvest (0.48, 0.46, 0.40 and 0.31 per cent, respectively) over other treatments. Paired row sowing with fertigation of 15 per cent RDF (22.5: 11: 11 kg ha^{-1}) applied in six equal splits (T_4) recorded significantly lower phosphorus content in stem at all growth stages. At 60 DAS phosphorus content in stem was non significant.

Effect of drip fertigation with only water soluble fertilizers had significant effect on phosphorus content in stem at all the growth stages except 60 DAS. However, paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) applied in six equal splits (T_1) recorded higher phosphorus content in stem at 90, 120, 150 DAS and at harvest (0.41, 0.39, 0.32 and 0.23 per cent, respectively) compared to other treatments.

Among different treatments involving either fertigation with only water soluble fertilizers or fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers, paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_5) recorded higher phosphorus content in stem at 90, 120, 150 DAS and at harvest (0.45, 0.44, 0.37 and 0.28 per cent, respectively) as compared to others.

4.5.5 Phosphorus content in leaf

The data on phosphorus content in leaf are presented in Table 22. Phosphorus content in leaf differed significantly due to different fertigation levels with conventional and water soluble fertilizers.

Influence of different fertigation levels in paired row sowing on phosphorus content in leaf was significant at all the growth stages. The data indicated that paired row sowing with fertigation of 100 per cent RDF (150:75:75 kg ha^{-1}) through conventional fertilizers applied in six equal splits (T_9) recorded significantly higher phosphorus content in leaf at 60, 90, 120, 150 DAS and at harvest (0.52, 0.54, 0.50,

Table 22: Phosphorus content in leaf of Bt cotton as influenced by fertigation levels with conventional and water soluble fertilizers

Treatment	Phosphorus content in leaf (%)				
	60 DAS	**90 DAS**	**120 DAS**	**150 DAS**	**At harvest**
T_1: Fertigation of 30% RDF through WSF	0.42	0.48	0.44	0.37	0.28
T_2: Fertigation of 25% RDF through WSF	0.41	0.47	0.44	0.36	0.27
T_3: Fertigation of 20% RDF through WSF	0.38	0.46	0.42	0.34	0.27
T_4: Fertigation of 15% RDF through WSF	0.36	0.40	0.36	0.26	0.19
T_5: Fertigation of 25% RDF through CF + T_1	0.48	0.53	0.49	0.41	0.33
T_6: Fertigation of 25% RDF through CF + T_2	0.47	0.50	0.47	0.39	0.31
T_7: Fertigation of 25% RDF through CF + T_3	0.44	0.50	0.46	0.38	0.29
T_8: Fertigation of 25% RDF through CF + T_4	0.43	0.48	0.45	0.37	0.28
T_9: Fertigation of conventional fertilizers with 100 % RDF	0.52	0.54	0.50	0.47	0.39
S. Em. ±	0.03	0.02	0.02	0.02	0.02
C.D. (P = 0.05)	0.08	0.07	0.07	0.07	0.06

DAS: Days after sowing, RDF: 150: 75: 75 N: P_2O_5: K_2O kg ha^{-1}, WSF: Water soluble fertilizer (19: 19: 19)

0.47 and 0.39 per cent, respectively) over other treatments. Paired row sowing with fertigation of 15 per cent RDF (22.5: 11: 11 kg ha^{-1}) applied in six equal splits (T_4) recorded significantly lower phosphorus content in leaf.

. Effect of drip fertigation with only water soluble fertilizers had significant effect on phosphorus content in stem at all the growth stages. However, paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) applied in six equal splits (T_1) recorded higher phosphorus content in leaf at 60, 90, 120, 150 DAS and at harvest (0.42, 0.48, 0.44, 0.37 and 0.28 per cent, respectively) compared to other treatments.

Among different treatments involving either fertigation with only water soluble fertilizers or fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers, paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_5) recorded higher phosphorus content in content in leaf at 60, 90, 120, 150 DAS and at harvest (0.48, 0.53, 0.49, 0.41 and 0.33 per cent, respectively) as compared to others.

4.5.6 Phosphorus content in reproductive parts

The data on phosphorus content in reproductive parts are presented in Table 23. Phosphorus content in reproductive parts differed significantly due to different fertigation levels with conventional and water soluble fertilizers.

Influence of different fertigation levels in paired row sowing on phosphorus content in leaf was significant at all the growth stages. The data indicated that paired row sowing with fertigation of 100 per cent RDF (150:75:75 kg ha^{-1}) through conventional fertilizers applied in six equal splits (T_9) recorded significantly higher phosphorus content in reproductive parts at 60, 90, 120, 150 DAS and at harvest (0.49, 0.56, 0.54, 0.47 and 0.35 per cent, respectively) over other treatments. Paired row sowing with fertigation of 15 per cent RDF (22.5: 11: 11 kg ha^{-1}) applied in six equal splits (T_4) recorded significantly lower phosphorus content in reproductive parts.

. Effect of drip fertigation with only water soluble fertilizers had significant effect on phosphorus content in reproductive parts at all the growth stages. However, paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) applied in six

Table 23: Phosphorus content in reproductive parts of Bt cotton as influenced by fertigation levels with conventional and water soluble fertilizers

Treatment	Phosphorus content in reproductive parts (%)				
	60 DAS	**90 DAS**	**120 DAS**	**150 DAS**	**At harvest**
T_1: Fertigation of 30% RDF through WSF	0.43	0.50	0.46	0.38	0.26
T_2: Fertigation of 25% RDF through WSF	0.40	0.47	0.44	0.36	0.24
T_3: Fertigation of 20% RDF through WSF	0.37	0.44	0.41	0.33	0.22
T_4: Fertigation of 15% RDF through WSF	0.31	0.38	0.35	0.28	0.17
T_5: Fertigation of 25% RDF through CF + T_1	0.47	0.54	0.51	0.43	0.32
T_6: Fertigation of 25% RDF through CF + T_2	0.45	0.53	0.49	0.41	0.29
T_7: Fertigation of 25% RDF through CF + T_3	0.45	0.52	0.48	0.40	0.28
T_8: Fertigation of 25% RDF through CF + T_4	0.44	0.51	0.47	0.39	0.28
T_9: Fertigation of conventional fertilizers with 100 % RDF	0.49	0.56	0.54	0.47	0.35
S. Em. ±	0.02	0.02	0.02	0.02	0.02
C.D. (P = 0.05)	0.07	0.07	0.06	0.06	0.05

DAS: Days after sowing, RDF: 150: 75: 75 N: P_2O_5: K_2O kg ha^{-1}, WSF: Water soluble fertilizer (19: 19: 19)

equal splits (T_1) recorded higher phosphorus content in reproductive parts at 60, 90, 120, 150 DAS and at harvest (0.43, 0.50, 0.46, 0.38 and 0.26 per cent, respectively) compared to other treatments.

Among different treatments involving either fertigation with only water soluble fertilizers or fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers, paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_5) recorded higher phosphorus content in content in reproductive parts at 60, 90, 120, 150 DAS and at harvest (0.47, 0.54, 0.51, 0.43 and 0.32 per cent, respectively) as compared to others.

4.5.7 Potassium content in stem

The data on potassium content in stem are presented in Table 24. Potassium content in stem differed significantly due to different fertigation levels with conventional and water soluble fertilizers.

Influence of different fertigation levels in paired row sowing on potassium content in stem was significant at all the growth stages. The data indicated that paired row sowing with fertigation of 100 per cent RDF (150:75:75 kg ha^{-1}) through conventional fertilizers applied in six equal splits (T_9) recorded significantly higher potassium content in stem at 60, 90, 120, 150 DAS and at harvest (0.70, 1.61, 1.34, 0.88 and 0.67 per cent, respectively) over other treatments. However, it was on par with paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_5) (0.64, 1.53, 1.25, 0.82 and 0.60 per cent, respectively) and paired row sowing with fertigation of 25 per cent RDF (37.5: 19: 19 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_6) at all growth stages except at harvest (0.63, 1.49, 1.22 and 0.80 per cent, respectively). Paired row sowing with fertigation of 15 per cent RDF (22.5: 11: 11 kg ha^{-1}) applied in six equal splits (T_4) recorded significantly lower potassium content in stem at all growth stages.

Table 24: Potassium content (%) in stem of Bt cotton as influenced by fertigation levels with conventional and water soluble fertilizers

Treatment	Potassium content in stem (%)				
	60 DAS	90 DAS	120 DAS	150 DAS	At harvest
T_1: Fertigation of 30% RDF through WSF	0.60	1.37	1.17	0.74	0.52
T_2: Fertigation of 25% RDF through WSF	0.59	1.31	1.12	0.70	0.50
T_3: Fertigation of 20% RDF through WSF	0.58	1.30	1.07	0.66	0.47
T_4: Fertigation of 15% RDF through WSF	0.57	1.23	0.98	0.59	0.43
T_5: Fertigation of 25% RDF through CF + T_1	0.64	1.53	1.25	0.82	0.60
T_6: Fertigation of 25% RDF through CF + T_2	0.63	1.49	1.22	0.80	0.57
T_7: Fertigation of 25% RDF through CF + T_3	0.61	1.45	1.21	0.77	0.56
T_8: Fertigation of 25% RDF through CF + T_4	0.61	1.41	1.18	0.75	0.54
T_9: Fertigation of conventional fertilizers with 100 % RDF	0.70	1.61	1.34	0.88	0.67
S. Em. ±	0.02	0.04	0.05	0.04	0.03
C.D. (P = 0.05)	0.07	0.13	0.14	0.11	0.09

DAS: Days after sowing, RDF: 150: 75: 75 N: P_2O_5: K_2O kg ha^{-1}, WSF: Water soluble fertilizer (19: 19: 19)

Effect of drip fertigation with only water soluble fertilizers had significant effect on potassium content in stem at all the growth stages. However, paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) applied in six equal splits (T_1) recorded higher potassium content in stem at 60, 90, 120, 150 DAS and at harvest (0.60, 1.37, 1.17, 0.74 and 0.52 per cent, respectively) compared to other treatments.

Among different treatments involving either fertigation with only water soluble fertilizers or fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers, treatments included fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers had significant effect on potassium content in stem compared to respective fertigation with water soluble fertilizers only. Paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_5) recorded higher potassium content in stem at 60, 90, 120, 150 DAS and at harvest (0.64, 1.53, 1.25, 0.82 and 0.60 per cent, respectively) as compared to others.

4.5.8 Potassium content in leaf

The data on potassium content in leaf are presented in Table 25. Potassium content in leaf differed significantly due to different fertigation levels with conventional and water soluble fertilizers.

Influence of different fertigation levels in paired row sowing on potassium content in leaf was significant at all the growth stages. The data indicated that paired row sowing with fertigation of 100 per cent RDF (150:75:75 kg ha^{-1}) through conventional fertilizers applied in six equal splits (T_9) recorded significantly higher potassium content in leaf at 60, 90, 120, 150 DAS and at harvest (0.73, 1.65, 1.30, 0.85 and 0.78 per cent, respectively) over other treatments. However, it was on par with paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_5) at growth stages except at harvest (0.70, 1.52, 1.21 and 0.77 per cent, respectively). Paired row sowing with fertigation of 15 per cent RDF (22.5: 11: 11 kg ha^{-1}) applied in six equal splits (T_4) recorded significantly lower potassium content in leaf at all growth stages.

Table 25: Potassium content in leaf of Bt cotton as influenced by fertigation levels with conventional and water soluble fertilizers

Treatments	Potassium content in leaf (%)				
	60 DAS	90 DAS	120 DAS	150 DAS	At harvest
T_1: Fertigation of 30% RDF through WSF	0.57	1.34	1.10	0.71	0.59
T_2: Fertigation of 25% RDF through WSF	0.54	1.28	1.08	0.66	0.56
T_3: Fertigation of 20% RDF through WSF	0.49	1.25	1.06	0.63	0.54
T_4: Fertigation of 15% RDF through WSF	0.45	1.15	0.95	0.55	0.49
T_5: Fertigation of 25% RDF through CF + T_1	0.70	1.52	1.21	0.77	0.68
T_6: Fertigation of 25% RDF through CF + T_2	0.64	1.48	1.17	0.76	0.65
T_7: Fertigation of 25% RDF through CF + T_3	0.59	1.36	1.15	0.74	0.63
T_8: Fertigation of 25% RDF through CF + T_4	0.58	1.35	1.13	0.73	0.61
T_9: Fertigation of conventional fertilizers with 100 % RDF	0.73	1.65	1.30	0.85	0.78
S. Em. ±	0.02	0.04	0.04	0.04	0.03
C.D. (P = 0.05)	0.05	0.13	0.12	0.11	0.09

DAS: Days after sowing, RDF: 150: 75: 75 N: P_2O_5: K_2O kg ha^{-1}, WSF: Water soluble fertilizer (19: 19: 19)

Effect of drip fertigation with only water soluble fertilizers had significant effect on potassium content in leaf at all the growth stages. However, paired row sowing with fertigation of 30 per cent RD (45: 22.5: 22.5 kg ha^{-1}) applied in six equal splits (T_1) recorded higher potassium content in leaf at 60, 90, 120, 150 DAS and at harvest (0.57, 1.34, 1.10, 0.71 and 0.59 per cent, respectively) compared to other treatments.

Among different treatments involving either fertigation with only water soluble fertilizers or fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers, paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_5) recorded higher potassium content in leaf at 60, 90, 120, 150 DAS and at harvest (0.70, 1.52, 1.21, 0.77 and 0.68 per cent, respectively) as compared to others.

4.5.9 Potassium content in reproductive parts

The data on potassium content in reproductive parts are presented in Table 26. Potassium content in reproductive parts differed significantly due to different fertigation levels with conventional and water soluble fertilizers.

Influence of different fertigation levels in paired row sowing on potassium content in reproductive parts was significant at all the growth stages. The data indicated that paired row sowing with fertigation of 100 per cent RDF (150:75:75 kg ha^{-1}) through conventional fertilizers applied in six equal splits (T_9) recorded significantly higher potassium content in reproductive parts at 60, 90, 120, 150 DAS and at harvest (0.70, 1.72, 2.34, 0.98 and 0.68 per cent, respectively) over other treatments. However, it was on par with paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_5) at 60, 120 and 150 DAS (0.67, 2.14 and 0.88 per cent, respectively). Paired row sowing with fertigation of 15 per cent RDF (22.5: 11: 11 kg ha^{-1}) applied in six equal splits (T_4) recorded significantly lower potassium content in reproductive parts at all growth stages.

Effect of drip fertigation with only water soluble fertilizers had significant effect on potassium content in reproductive parts at all the growth stages. Paired row sowing

Table 26: Potassium content in reproductive parts of Bt cotton as influenced by fertigation levels with conventional and water soluble fertilizers

Treatment	Potassium content in reproductive (%)				
	60 DAS	**90 DAS**	**120 DAS**	**150 DAS**	**At harvest**
T_1: Fertigation of 30% RDF through WSF	0.55	1.37	1.88	0.81	0.51
T_2: Fertigation of 25% RDF through WSF	0.54	1.31	1.76	0.76	0.49
T_3: Fertigation of 20% RDF through WSF	0.50	1.22	1.66	0.72	0.46
T_4: Fertigation of 15% RDF through WSF	0.47	1.08	1.44	0.62	0.37
T_5: Fertigation of 25% RDF through CF + T_1	0.67	1.57	2.14	0.88	0.60
T_6: Fertigation of 25% RDF through CF + T_2	0.64	1.51	2.07	0.86	0.57
T_7: Fertigation of 25% RDF through CF + T_3	0.57	1.42	1.96	0.84	0.55
T_8: Fertigation of 25% RDF through CF + T_4	0.56	1.40	1.91	0.82	0.54
T_9: Fertigation of conventional fertilizers with 100 % RDF	0.70	1.72	2.34	0.98	0.68
S. Em. ±	0.02	0.04	0.07	0.03	0.02
C.D. (P = 0.05)	0.06	0.13	0.20	0.10	0.06

DAS: Days after sowing, RDF: 150: 75: 75 N: P_2O_5: K_2O kg ha^{-1}, WSF: Water soluble fertilizer (19: 19: 19)

with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) applied in six equal splits (T_1) recorded higher potassium content in reproductive parts at 60, 90, 120, 150 DAS and at harvest (0.55, 1.37, 1.88, 0.81 and 0.51 per cent, respectively) compared to other treatments.

Among different treatments involving either fertigation with only water soluble fertilizers or fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers, paired row sowing with fertigation of 30 per RDF (45: 22.5: 22.5 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_5) recorded higher potassium content in reproductive parts at 60, 90, 120, 150 DAS and at harvest (0.67, 1.57, 2.14, 0.88 and 0.60 per cent, respectively) as compared to others, but on par with paired row sowing with fertigation of 25 per cent RDF (37.5: 19: 19 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_6) (0.64, 1.51, 2.07, 0.86 and 0.57 per cent, respectively).

4.5.10 Nitrogen uptake in stem

The data on nitrogen uptake in stem are presented in Table 27. The nitrogen uptake in stem differed significantly among the treatments.

Paired row sowing with fertigation of 100 per cent RDF (150:75:75 kg ha^{-1}) through conventional fertilizers applied in six equal splits (T_9) recorded significantly higher nitrogen uptake in stem at 60, 90, 120, 150 DAS and at harvest (12.34, 29.60, 30.04, 35.93 and 34.14 kg ha^{-1}, respectively) over other treatments and was on par with paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_5) at 60 DAS and at harvest (11.48 and 29.81 kg ha^{-1}, respectively). Paired row sowing with fertigation of 15 per cent RDF (22.5: 11: 11 kg ha^{-1}) applied in six equal splits (T_4) recorded significantly lower nitrogen uptake in stem at all growth stages.

Drip fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers had significant effect on nitrogen uptake in stem compared to respective fertigation with water soluble fertilizers only. Among the treatments

Table 27: Nitrogen uptake in stem of Bt cotton as influenced by fertigation levels with conventional and water soluble fertilizers

Treatment	Nitrogen uptake in stem (kg ha^{-1})				
	60 DAS	90 DAS	120 DAS	150 DAS	At harvest
T_1: Fertigation of 30% RDF through WSF	7.52	16.30	16.93	19.25	18.25
T_2: Fertigation of 25% RDF through WSF	7.08	15.39	15.96	17.81	16.84
T_3: Fertigation of 20% RDF through WSF	6.01	13.21	15.25	16.74	15.86
T_4: Fertigation of 15% RDF through WSF	5.62	11.67	12.85	12.91	12.54
T_5: Fertigation of 25% RDF through CF + T_1	11.48	23.74	25.06	31.54	29.81
T_6: Fertigation of 25% RDF through CF + T_2	9.43	21.27	23.37	27.04	26.67
T_7: Fertigation of 25% RDF through CF + T_3	8.69	19.82	20.05	25.05	23.54
T_8: Fertigation of 25% RDF through CF + T_4	7.94	18.09	18.53	19.19	19.15
T_9: Fertigation of conventional fertilizers with 100 % RDF	12.34	29.60	30.04	35.93	34.14
S. Em. ±	0.42	1.03	1.31	1.36	1.47
C.D. (P=0.05)	1.27	3.08	3.93	4.06	4.40

DAS: Days after sowing, RDF: 150: 75: 75 N: P_2O_5: K_2O kg ha^{-1}, WSF: Water soluble fertilizer (19: 19: 19)

involving fertigation with only water soluble fertilizers, paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) applied in six equal splits (T_1) recorded higher nitrogen uptake in stem at 60, 90, 120, 150 DAS and at harvest (7.52, 16.30, 16.93, 19.25 and 18.25 kg ha^{-1}, respectively) compared to other treatments.

4.5.11 Nitrogen uptake in leaf

The data on nitrogen uptake in leaf are presented in Table 28. The nitrogen uptake in leaf differed significantly among the treatments.

Paired row sowing with fertigation of 100 per cent RDF (150:75:75 kg ha^{-1}) through conventional fertilizers applied in six equal splits (T_9) recorded significantly higher nitrogen uptake in leaf at 60, 90, 120, 150 DAS and at harvest (21.52, 61.80, 68.96, 42.14 and 24.63 kg ha^{-1}, respectively) over other treatments. Paired row sowing with fertigation of 15 per cent RDF (22.5: 11: 11 kg ha^{-1}) applied in six equal splits (T_4) recorded significantly lower nitrogen uptake in leaf at all growth stages.

Drip fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers had significant effect on nitrogen uptake in leaf compared to respective fertigation with water soluble fertilizers only. Paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_5) recorded higher nitrogen uptake in leaf at 60, 90, 120, 150 DAS and at harvest (16.31, 45.97, 50.96, 28.65 and 15.14 kg ha^{-1}, respectively) compared to others and was on par with paired row sowing with fertigation of 25 per cent RDF (37.5: 19: 19 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_6) at 60, 90, 120 DAS and at harvest (15.39, 41.76, 47.64 and 13.36 kg ha^{-1}, respectively). Among the treatments involving fertigation with only water soluble fertilizers, paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) applied in six equal splits (T_1) recorded higher nitrogen uptake in leaf at 60, 90, 120, 150 DAS and at harvest (12.24, 33.24, 39.06, 18.89 and 9.78 kg ha^{-1}, respectively) compared to other treatments.

Table 28: Nitrogen uptake in leaf of Bt cotton as influenced by fertigation levels with conventional and water soluble

Treatment	Nitrogen uptake in leaf (kg ha^{-1})				
	60 DAS	**90 DAS**	**120 DAS**	**150 DAS**	**At harvest**
T_1: Fertigation of 30% RDF through WSF	12.24	33.24	39.06	18.89	9.78
T_2: Fertigation of 25% RDF through WSF	11.48	32.27	36.29	17.87	9.11
T_3: Fertigation of 20% RDF through WSF	9.90	30.07	32.56	15.41	7.90
T_4: Fertigation of 15% RDF through WSF	9.11	29.39	24.34	13.83	6.72
T_5: Fertigation of 25% RDF through CF + T_1	16.31	45.97	50.96	28.65	15.14
T_6: Fertigation of 25% RDF through CF + T_2	15.39	41.76	47.64	25.14	13.36
T_7: Fertigation of 25% RDF through CF + T_3	13.44	38.68	44.91	22.21	12.55
T_8: Fertigation of 25% RDF through CF + T_4	12.67	37.01	41.36	20.93	11.37
T_9: Fertigation of conventional fertilizers with 100 % RDF	21.52	61.80	68.96	42.14	24.63
S. Em. ±	0.65	2.00	4.04	1.07	0.89
C.D. (P=0.05)	1.95	5.99	12.12	3.22	2.66

DAS: Days after sowing, RDF: 150: 75: 75 N: P_2O_5: K_2O kg ha^{-1}, WSF: Water soluble fertilizer (19: 19: 19)

4.5.12 Nitrogen uptake in reproductive parts

The data on nitrogen uptake in reproductive parts are presented in Table 29. The nitrogen uptake in reproductive parts differed significantly among the treatments.

Paired row sowing with fertigation of 100 per cent RDF (150:75:75 kg ha^{-1}) through conventional fertilizers applied in six equal splits (T_9) recorded significantly higher nitrogen uptake in reproductive parts at 60, 90, 120, 150 DAS and at harvest (7.76, 58.93, 70.33, 70.11 and 46.10 kg ha^{-1}, respectively) over other treatments. Paired row sowing with fertigation of 15 per cent RDF (22.5: 11: 11 kg ha^{-1}) applied in six equal splits (T_4) recorded significantly lower nitrogen uptake in reproductive parts at all growth stages.

Drip fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers had significant effect on nitrogen uptake in reproductive parts compared to respective fertigation with water soluble fertilizers only. Paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_5) recorded higher nitrogen uptake in reproductive parts at 60, 90, 120, 150 DAS and at harvest (6.76, 48.14, 61.08, 57.65 and 38.31 kg ha^{-1}, respectively) compared to others and was on par with paired row sowing with fertigation of 25 per cent RDF (37.5: 19: 19 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_6) (6.24, 44.09, 56.19, 55.75 and 32.95 kg ha^{-1}, respectively). Among the treatments involving fertigation with only water soluble fertilizers, paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) applied in six equal splits (T_1) recorded higher nitrogen in reproductive parts at 60, 90, 120, 150 DAS and at harvest (4.91, 35..55, 50.04, 45.36 and 27.72 kg ha^{-1}, respectively) compared to other treatments.

4.5.13 Total nitrogen uptake

The data on total nitrogen uptake are presented in Table 30. Total nitrogen uptake differed significantly among the treatments.

Paired row sowing with fertigation of 100 per cent RDF (150:75:75 kg ha^{-1}) through conventional fertilizers applied in six equal splits (T_9) recorded significantly

Table 29: Nitrogen uptake in reproductive parts of Bt cotton as influenced by fertigation levels with conventional and water soluble fertilizers

Treatment	Nitrogen uptake in reproductive parts (kg ha^{-1})				
	60 DAS	90 DAS	120 DAS	150 DAS	At harvest
T_1: Fertigation of 30% RDF through WSF	4.91	35.55	50.04	45.36	27.72
T_2: Fertigation of 25% RDF through WSF	4.62	34.09	47.16	43.78	25.52
T_3: Fertigation of 20% RDF through WSF	4.48	29.97	44.83	41.73	23.27
T_4: Fertigation of 15% RDF through WSF	4.35	27.29	32.71	27.18	20.23
T_5: Fertigation of 25% RDF through CF + T_1	6.76	48.14	61.08	57.65	38.31
T_6: Fertigation of 25% RDF through CF + T_2	6.24	44.09	56.19	55.75	32.95
T_7: Fertigation of 25% RDF through CF + T_3	5.81	43.32	54.00	50.00	30.02
T_8: Fertigation of 25% RDF through CF + T_4	5.13	39.90	50.68	47.68	28.70
T_9: Fertigation of conventional fertilizers with 100 % RDF	7.76	58.93	70.33	70.11	46.10
S. Em. ±	0.24	1.61	2.36	2.34	1.57
C.D. (P=0.05)	0.72	4.83	7.07	7.01	4.72

DAS: Days after sowing, RDF: 150: 75: 75 N: P_2O_5: K_2O kg ha^{-1}, WSF: Water soluble fertilizer (19: 19: 19)

Table 30: Total nitrogen uptake of Bt cotton as influenced by fertigation levels with conventional and water soluble fertilizers

Treatment	Total nitrogen uptake (kg ha^{-1})				
	60 DAS	90 DAS	120 DAS	150 DAS	At harvest
T_1: Fertigation of 30% RDF through WSF	24.68	85.09	106.02	83.50	55.74
T_2: Fertigation of 25% RDF through WSF	23.19	81.75	99.42	79.46	51.46
T_3: Fertigation of 20% RDF through WSF	20.38	73.24	92.64	73.88	47.03
T_4: Fertigation of 15% RDF through WSF	19.08	68.35	69.90	53.93	39.49
T_5: Fertigation of 25% RDF through CF + T_1	34.55	117.85	137.10	117.84	83.26
T_6: Fertigation of 25% RDF through CF + T_2	31.05	107.12	127.20	107.93	72.98
T_7: Fertigation of 25% RDF through CF + T_3	27.94	101.82	118.96	97.26	66.12
T_8: Fertigation of 25% RDF through CF + T_4	25.74	95.00	110.56	87.79	59.22
T_9: Fertigation of conventional fertilizers with 100 % RDF	41.62	150.32	169.32	148.18	104.87
S. Em. ±	0.77	3.80	6.20	3.54	1.95
C.D. (P=0.05)	2.32	11.38	18.58	10.61	5.85

DAS: Days after sowing, RDF: 150: 75: 75 N: P_2O_5: K_2O kg ha^{-1}, WSF: Water soluble fertilizer (19: 19: 19)

higher higher total nitrogen uptake at 60, 90, 120, 150 DAS and at harvest (41.62, 150.32, 169.32, 148.18 and 104.87 kg ha^{-1}, respectively) over other treatments. Paired row sowing with fertigation of 15 per cent RDF (22.5: 11: 11 kg ha^{-1}) applied in six equal splits (T_4) recorded significantly lower total nitrogen uptake at all growth stages.

Drip fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers had significant effect on total nitrogen uptake compared to respective fertigation with water soluble fertilizers only. Paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_5) recorded higher total nitrogen uptake at 60, 90, 120, 150 DAS and at harvest (34.55, 117.85, 137.10, 117.84 and 83.26 kg ha^{-1}, respectively) compared to others and was on par with paired row sowing with fertigation of 25 per cent RDF (37.5: 19: 19 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_6) at 90,120 and 150 DAS(107.12, 127.20 and 107.93 kg ha^{-1}, respectively). Among the treatments involving fertigation with only water soluble fertilizers, paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) applied in six equal splits (T_1) recorded total nitrogen uptake at 60, 90, 120, 150 DAS and at harvest (24.68, 85.09, 106.02, 83.50 and 55.74 kg ha^{-1}, respectively) compared to other treatments.

4.5.14 Phosphorus uptake in stem

The data on phosphorus uptake in stem are presented in Table 31. The phosphorus uptake in stem differed significantly among the treatments.

Paired row sowing with fertigation of 100 per cent RDF (150:75:75 kg ha^{-1}) through conventional fertilizers applied in six equal splits (T_9) recorded significantly higher phosphorus uptake in stem at 60, 90, 120, 150 DAS and at harvest (2.46, 5.54, 8.33, 9.13 and 8.17 kg ha^{-1}, respectively) over other treatments and was on par with paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_5) at 60, 90 DAS and at harvest (2.27, 4.99 and 6.83 kg ha^{-1}, respectively). Paired row sowing with fertigation of 15 per cent RDF (22.5: 11: 11 kg

Table 31: Phosphorus uptake in stem of Bt cotton as influenced by fertigation levels with conventional and water soluble fertilizers

Treatment	Phosphorus uptake in stem (kg ha^{-1})				
	60 DAS	90 DAS	120 DAS	150 DAS	At harvest
T_1: Fertigation of 30% RDF through WSF	1.74	3.66	5.08	6.01	4.82
T_2: Fertigation of 25% RDF through WSF	1.63	3.33	4.50	5.27	4.09
T_3: Fertigation of 20% RDF through WSF	1.37	3.02	4.31	4.96	3.91
T_4: Fertigation of 15% RDF through WSF	1.19	2.45	3.62	3.89	2.79
T_5: Fertigation of 25% RDF through CF + T_1	2.27	4.99	7.06	7.61	6.83
T_6: Fertigation of 25% RDF through CF + T_2	2.19	4.61	6.68	7.30	6.09
T_7: Fertigation of 25% RDF through CF + T_3	1.98	4.38	5.85	6.64	5.73
T_8: Fertigation of 25% RDF through CF + T_4	1.84	4.19	5.50	6.35	5.00
T_9: Fertigation of conventional fertilizers with 100 % RDF	2.46	5.54	8.33	9.13	8.17
S. Em. ±	0.14	0.34	0.40	0.47	0.45
C.D. (P=0.05)	0.41	1.02	1.20	1.41	1.34

DAS: Days after sowing, RDF: 150: 75: 75 N: P_2O_5: K_2O kg ha^{-1}, WSF: Water soluble fertilizer (19: 19: 19)

ha^{-1}) applied in six equal splits (T_4) recorded significantly lower phosphorus uptake in stem at all growth stages.

Drip fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers had significant effect on phosphorus uptake in stem compared to respective fertigation with water soluble fertilizers only. Among the treatments involving fertigation with only water soluble fertilizers, paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) applied in six equal splits (T_1) recorded higher phosphorus uptake in stem at 60, 90, 120, 150 DAS and at harvest (1.74, 3.66, 5.08, 6.01 and 4.82 kg ha^{-1}, respectively) compared to other treatments.

4.5.15 Phosphorus uptake in leaf

The data on phosphorus uptake in leaf are presented in Table 32. The phosphorus uptake in leaf differed significantly among the treatments.

Paired row sowing with fertigation of 100 per cent RDF (150:75:75 kg ha^{-1}) through conventional fertilizers applied in six equal splits (T_9) recorded significantly higher phosphorus uptake in leaf at 60, 90, 120, 150 DAS and at harvest (3.00, 6.84, 9.91, 5.96 and 3.78 kg ha^{-1}, respectively) over other treatments and was on par with paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_5) at 60, 90 and 120 DAS (2.67, 6.22 and 9.10 kg ha^{-1}, respectively). Paired row sowing with fertigation of 15 per cent RDF (22.5: 11: 11 kg ha^{-1}) applied in six equal splits (T_4) recorded significantly lower phosphorus uptake in leaf at all growth stages.

Drip fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers had significant effect on phosphorus uptake in stem compared to respective fertigation with water soluble fertilizers only. Among the treatments involving fertigation with only water soluble fertilizers, paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) applied in six equal splits (T_1) recorded higher phosphorus uptake in leaf at 60, 90, 120, 150 DAS and at harvest (1.98, 4.52, 7.28, 3.54 and 1.80 kg ha^{-1}, respectively) compared to other treatments.

Table 32: Phosphorus uptake in leaf of Bt cotton as influenced by fertigation levels with conventional and water soluble fertilizers

Treatment	Phosphorus uptake in leaf (kg ha^{-1})				
	60 DAS	90 DAS	120 DAS	150 DAS	At harvest
T_1: Fertigation of 30% RDF through WSF	1.98	4.52	7.28	3.54	1.80
T_2: Fertigation of 25% RDF through WSF	1.84	4.30	7.09	3.43	1.71
T_3: Fertigation of 20% RDF through WSF	1.50	3.93	6.54	3.02	1.52
T_4: Fertigation of 15% RDF through WSF	1.34	3.37	4.72	2.31	1.06
T_5: Fertigation of 25% RDF through CF + T_1	2.67	6.22	9.10	4.80	2.86
T_6: Fertigation of 25% RDF through CF + T_2	2.53	5.48	8.48	4.40	2.52
T_7: Fertigation of 25% RDF through CF + T_3	2.19	5.34	8.09	4.15	2.30
T_8: Fertigation of 25% RDF through CF + T_4	2.05	5.05	7.57	3.90	2.09
T_9: Fertigation of conventional fertilizers with 100 % RDF	3.00	6.84	9.91	5.96	3.78
S. Em. ±	0.16	0.34	0.67	0.29	0.21
C.D. (P=0.05)	0.47	1.02	2.01	0.87	0.62

DAS: Days after sowing, RDF: 150: 75: 75 N: P_2O_5: K_2O kg ha^{-1}, WSF: Water soluble fertilizer (19: 19: 19)

4.5.16 Phosphorus uptake in reproductive parts

The data on phosphorus uptake in reproductive parts are presented in Table 33. The phosphorus uptake in reproductive parts differed significantly among the treatments.

Paired row sowing with fertigation of 100 per cent RDF (150:75:75 kg ha^{-1}) through conventional fertilizers applied in six equal splits (T_9) recorded significantly higher phosphorus uptake in reproductive parts at 60, 90, 120, 150 DAS and at harvest (0.98, 7.63, 11.88, 11.46 and 9.19 kg ha^{-1}, respectively) over other treatments and was on par with paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_5) at 60 and 90 DAS (0.86 and 6.72 kg ha^{-1}, respectively). Paired row sowing with fertigation of 15 per cent RDF (22.5: 11: 11 kg ha^{-1}) applied in six equal splits (T_4) recorded significantly lower phosphorus uptake in reproductive parts at all growth stages.

Drip fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers had significant effect on phosphorus uptake in stem compared to respective fertigation with water soluble fertilizers only. Paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_5) recorded higher phosphorus uptake in reproductive parts at 60, 90, 120, 150 DAS and at harvest (0.86, 6.72, 10.26, 9.81 and 7.77 kg ha^{-1}, respectively) as compared to others. Among the treatments involving fertigation with only water soluble fertilizers, paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) applied in six equal splits (T_1) recorded higher phosphorus uptake in in reproductive parts at 60, 90, 120, 150 DAS and at harvest (0.72, 5.19, 8.42, 7.88 and 5.89 kg ha^{-1}, respectively) compared to other treatments.

4.5.17 Total phosphorus uptake

The data on total phosphorus uptake are presented in Table 34. Total phosphorus uptake differed significantly among the treatments.

Table 33: Phosphorus uptake in reproductive parts of Bt cotton as influenced by fertigation levels with conventional and water soluble fertilizers

Treatment	Phosphorus uptake in reproductive parts (kg ha^{-1})				
	60 DAS	**90 DAS**	**120 DAS**	**150 DAS**	**At harvest**
T_1: Fertigation of 30% RDF through WSF	0.72	5.19	8.42	7.88	5.89
T_2: Fertigation of 25% RDF through WSF	0.67	4.78	7.80	7.31	5.43
T_3: Fertigation of 20% RDF through WSF	0.62	4.20	7.08	6.52	4.80
T_4: Fertigation of 15% RDF through WSF	0.52	3.54	5.76	5.36	3.65
T_5: Fertigation of 25% RDF through CF + T_1	0.86	6.72	10.26	9.81	7.77
T_6: Fertigation of 25% RDF through CF + T_2	0.80	6.25	9.80	9.16	6.88
T_7: Fertigation of 25% RDF through CF + T_3	0.78	6.09	9.21	8.64	6.41
T_8: Fertigation of 25% RDF through CF + T_4	0.76	5.83	8.76	8.30	6.24
T_9: Fertigation of conventional fertilizers with 100 % RDF	0.98	7.63	11.88	11.46	9.19
S. Em. ±	0.04	0.35	0.53	0.48	0.37
C.D. (P=0.05)	0.13	1.06	1.58	1.44	1.10

DAS: Days after sowing, RDF: 150: 75: 75 N: P_2O_5: K_2O kg ha^{-1}, WSF: Water soluble fertilizer (19: 19: 19)

Paired row sowing with fertigation of 100 per cent RDF (150:75:75 kg ha^{-1}) through conventional fertilizers applied in six equal splits (T_9) recorded significantly higher total phosphorus uptake at 60, 90, 120, 150 DAS and at harvest (6.45, 20.01, 30.12, 26.55 and 21.14 kg ha^{-1}, respectively) over other treatments and was on par with paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_5) at 60, 90 and 120 DAS (5.80, 17.94 and 26.42 kg ha^{-1}, respectively). Paired row sowing with fertigation of 15 per cent RDF (22.5: 11: 11 kg ha^{-1}) applied in six equal splits (T_4) recorded significantly lower total phosphorus uptake at all growth stages.

Drip fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers had significant effect on phosphorus uptake in stem compared to respective fertigation with water soluble fertilizers only. Paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_5) recorded higher total phosphorus uptake at 60, 90, 120, 150 DAS and at harvest (5.80, 17.94, 26.42, 22.22 and 17.45 kg ha^{-1}, respectively) as compared to others. Among the treatments involving fertigation with only water soluble fertilizers, paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) applied in six equal splits (T_1) recorded higher total phosphorus uptake at 60, 90, 120, 150 DAS and at harvest (4.44, 13.38, 20.79, 17.43 and 12.51 kg ha^{-1}, respectively) compared to other treatments.

4.5.18 Potassium uptake in stem

The data on potassium uptake in stem are presented in Table 35. The potassium uptake in stem differed significantly among the treatments.

Paired row sowing with fertigation of 100 per cent RDF (150:75:75 kg ha^{-1}) through conventional fertilizers applied in six equal splits (T_9) recorded significantly higher potassium uptake in stem at 60, 90, 120, 150 DAS and at harvest (4.24, 18.74, 24.08, 20.21 and 17.54 kg ha^{-1}, respectively) over other treatments and was on par with paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_5) at 60 DAS (3.75 kg ha^{-1}). Paired row sowing with fertigation of 15

Table 34: Total phosphorus uptake of Bt cotton as influenced by fertigation levels with conventional and water soluble fertilizers

Treatment	Total phosphorus uptake (kg ha^{-1})				
	60 DAS	90 DAS	120 DAS	150 DAS	At harvest
T_1: Fertigation of 30% RDF through WSF	4.44	13.38	20.79	17.43	12.51
T_2: Fertigation of 25% RDF through WSF	4.14	12.41	19.39	16.00	11.24
T_3: Fertigation of 20% RDF through WSF	3.49	11.15	17.94	14.50	10.22
T_4: Fertigation of 15% RDF through WSF	3.05	9.37	14.10	11.55	7.62
T_5: Fertigation of 25% RDF through CF + T_1	5.80	17.94	26.42	22.22	17.45
T_6: Fertigation of 25% RDF through CF + T_2	5.52	16.35	24.96	20.86	15.49
T_7: Fertigation of 25% RDF through CF + T_3	4.95	15.81	23.15	19.43	14.44
T_8: Fertigation of 25% RDF through CF + T_4	4.65	15.06	21.84	18.55	13.60
T_9: Fertigation of conventional fertilizers with 100 % RDF	6.45	20.01	30.12	26.55	21.14
S. Em. ±	0.24	0.86	1.27	0.98	0.68
C.D. (P=0.05)	0.73	2.59	3.81	2.94	2.05

DAS: Days after sowing, RDF: 150: 75: 75 N: P_2O_5: K_2O kg ha^{-1}, WSF: Water soluble fertilizer (19: 19: 19)

Table 35: Potassium uptake in stem of Bt cotton as influenced by fertigation levels with conventional and water soluble fertilizers

Treatment	Potassium uptake in stem (kg ha^{-1})				
	60 DAS	90 DAS	120 DAS	150 DAS	At harvest
T_1: Fertigation of 30% RDF through WSF	3.00	12.12	15.37	13.84	10.86
T_2: Fertigation of 25% RDF through WSF	2.82	11.23	14.18	12.78	10.08
T_3: Fertigation of 20% RDF through WSF	2.48	10.33	13.37	11.93	9.45
T_4: Fertigation of 15% RDF through WSF	2.31	9.02	10.03	9.85	8.36
T_5: Fertigation of 25% RDF through CF + T_1	3.75	16.94	20.15	16.99	14.64
T_6: Fertigation of 25% RDF through CF + T_2	3.60	15.33	19.08	16.44	13.40
T_7: Fertigation of 25% RDF through CF + T_3	3.26	14.35	17.40	15.31	12.69
T_8: Fertigation of 25% RDF through CF + T_4	3.12	13.35	16.28	14.41	11.47
T_9: Fertigation of conventional fertilizers with 100 % RDF	4.24	18.74	24.08	20.21	17.54
S. Em. ±	0.17	0.53	1.02	0.75	0.82
C.D. (P=0.05)	0.51	1.58	3.07	2.24	2.46

DAS: Days after sowing, RDF: 150: 75: 75 N: P_2O_5: K_2O kg ha^{-1}, WSF: Water soluble fertilizer (19: 19: 19)

per cent RDF (22.5: 11: 11 kg ha^{-1}) applied in six equal splits (T_4) recorded significantly lower potassium uptake in stem at all growth stages.

Drip fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers had significant effect on potassium uptake in stem compared to respective fertigation with water soluble fertilizers only. Paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_5) recorded higher potassium uptake in stem at 60, 90, 120, 150 DAS and at harvest (3.75, 16.94, 20.15, 16.99 and 14.64 kg ha^{-1}, respectively) as compared to others. Among the treatments involving fertigation with only water soluble fertilizers, paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) applied in six equal splits (T_1) recorded higher potassium uptake in stem at 60, 90, 120, 150 DAS and at harvest (3.00, 12.12, 15.37, 13.84 and 10.86 kg ha^{-1}, respectively) compared to other treatments.

4.5.19 Potassium uptake in leaf

The data on potassium uptake in leaf are presented in Table 36. The potassium uptake in leaf differed significantly among the treatments.

Paired row sowing with fertigation of 100 per cent RDF (150:75:75 kg ha^{-1}) through conventional fertilizers applied in six equal splits (T_9) recorded significantly higher potassium uptake in leaf at 60, 90, 120, 150 DAS and at harvest (4.18, 20.77, 25.40, 10.87 and 7.52 kg ha^{-1}, respectively) over other treatments and was on par with paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_5) at 60 and 120 DAS (3.87 and 22.43 kg ha^{-1}, respectively).Paired row sowing with fertigation of 15 per cent RDF (22.5: 11: 11 kg ha^{-1}) applied in six equal splits (T_4) recorded significantly lower potassium uptake in leaf at all growth stages.

Drip fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers had significant effect on potassium uptake in leaf compared to respective fertigation with water soluble fertilizers only. Paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) through water soluble fertilizer

Table 36: Potassium uptake in leaf Bt cotton as influenced by fertigation levels with conventional and water soluble fertilizers

Treatment	Potassium uptake in leaf (kg ha^{-1})				
	60 DAS	90 DAS	120 DAS	150 DAS	At harvest
T_1: Fertigation of 30% RDF through WSF	2.69	12.64	18.08	6.89	3.83
T_2: Fertigation of 25% RDF through WSF	2.43	11.76	17.26	6.23	3.56
T_3: Fertigation of 20% RDF through WSF	1.92	10.82	16.73	5.58	3.09
T_4: Fertigation of 15% RDF through WSF	1.70	9.76	12.62	4.78	2.74
T_5: Fertigation of 25% RDF through CF + T_1	3.87	17.73	22.43	8.99	5.81
T_6: Fertigation of 25% RDF through CF + T_2	3.46	16.17	21.15	8.53	5.29
T_7: Fertigation of 25% RDF through CF + T_3	2.96	14.67	20.20	8.17	5.00
T_8: Fertigation of 25% RDF through CF + T_4	2.76	14.09	18.97	7.69	4.59
T_9: Fertigation of conventional fertilizers with 100 % RDF	4.18	20.77	25.40	10.87	7.52
S. Em. ±	0.12	0.53	1.38	0.50	0.38
C.D. (P=0.05)	0.35	1.58	4.15	1.50	1.13

DAS: Days after sowing, RDF: 150: 75: 75 N: P_2O_5: K_2O kg ha^{-1}, WSF: Water soluble fertilizer (19: 19: 19)

and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_5) recorded higher potassium uptake in leaf at 60, 90, 120, 150 DAS and at harvest (3.87, 17.73, 22.43, 8.99 and 5.81 kg ha^{-1}, respectively) as compared to others. Among the treatments involving fertigation with only water soluble fertilizers, paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) applied in six equal splits (T_1) recorded higher potassium uptake in leaf at 60, 90, 120, 150 DAS and at harvest (2.69, 12.64, 18.08, 6.89 and 3.83 kg ha^{-1}, respectively) compared to other treatments.

4.5.20 Potassium uptake in reproductive parts

The data on potassium uptake in reproductive parts are presented in Table 37. The potassium uptake in reproductive parts differed significantly among the treatments.

Paired row sowing with fertigation of 100 per cent RDF (150:75:75 kg ha^{-1}) through conventional fertilizers applied in six equal splits (T_9) recorded significantly higher potassium uptake in reproductive parts at 60, 90, 120, 150 DAS and at harvest (1.40, 23.26, 51.64, 24.03 and 17.70 kg ha^{-1}, respectively) over other treatments. Paired row sowing with fertigation of 15 per cent RDF (22.5: 11: 11 kg ha^{-1}) applied in six equal splits (T_4) recorded significantly lower potassium uptake in reproductive parts at all growth stages.

Drip fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers had significant effect on potassium uptake in reproductive parts compared to respective fertigation with water soluble fertilizers only. Paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_5) recorded higher potassium uptake in reproductive parts at 60, 90, 120, 150 DAS and at harvest (1.23, 19.52, 43.35, 20.05 and 14.74 kg ha^{-1}, respectively) as compared to others. Among the treatments involving fertigation with only water soluble fertilizers, paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) applied in six equal splits (T_1) recorded higher potassium uptake in reproductive parts at 60, 90, 120, 150 DAS and at harvest (0.93, 14.31, 34.02, 16.67 and 11.43 kg ha^{-1}, respectively) compared to other treatments.

Table 37: Potassium uptake in reproductive parts of Bt cotton as influenced by fertigation levels with conventional and water soluble fertilizers

Treatment	Potassium uptake in reproductive parts (kg ha^{-1})				
	60 DAS	90 DAS	120 DAS	150 DAS	At harvest
T_1: Fertigation of 30% RDF through WSF	0.93	14.31	34.02	16.67	11.43
T_2: Fertigation of 25% RDF through WSF	0.91	13.36	31.13	15.43	10.83
T_3: Fertigation of 20% RDF through WSF	0.84	11.61	28.91	14.43	10.27
T_4: Fertigation of 15% RDF through WSF	0.77	9.97	23.64	11.80	8.12
T_5: Fertigation of 25% RDF through CF + T_1	1.23	19.52	43.35	20.05	14.74
T_6: Fertigation of 25% RDF through CF + T_2	1.13	17.99	41.45	19.38	13.47
T_7: Fertigation of 25% RDF through CF + T_3	1.00	16.72	37.74	18.01	12.64
T_8: Fertigation of 25% RDF through CF + T_4	0.96	15.88	35.41	17.28	12.16
T_9: Fertigation of conventional fertilizers with 100 % RDF	1.40	23.26	51.64	24.03	17.70
S. Em. ±	0.05	0.74	2.03	0.99	0.58
C.D. (P=0.05)	0.14	2.23	6.08	2.96	1.75

DAS: Days after sowing, RDF: 150: 75: 75 N: P_2O_5: K_2O kg ha^{-1}, WSF: Water soluble fertilizer (19: 19: 19)

4.5.21 Total Potassium uptake

The data on total potassium uptake are presented in Table 38. Total potassium uptake differed significantly among the treatments.

Paired row sowing with fertigation of 100 per cent RDF (150:75:75 kg ha^{-1}) through conventional fertilizers applied in six equal splits (T_9) recorded significantly higher total potassium uptake at 60, 90, 120, 150 DAS and at harvest (9.82, 62.77, 101.11, 55.11 and 42.76 kg ha^{-1}, respectively) over other treatments. Paired row sowing with fertigation of 15 per cent RDF (22.5: 11: 11 kg ha^{-1}) applied in six equal splits (T_4) recorded significantly lower total potassium uptake at all growth stages.

Drip fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers had significant effect on phosphorus uptake in stem compared to respective fertigation with water soluble fertilizers only. Paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_5) recorded higher total potassium uptake at 60, 90, 120, 150 DAS and at harvest (8.85, 54.19, 85.93, 46.03 and 35.19 kg ha^{-1}, respectively) as compared to others. Among the treatments involving fertigation with only water soluble fertilizers, paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) applied in six equal splits (T_1) recorded higher total potassium uptake at 60, 90, 120, 150 DAS and at harvest (6.62, 39.06, 67.48, 37.40 and 26.13 kg ha^{-1}, respectively) compared to other treatments.

4.5.22 Soil available nitrogen

The data on soil available nitrogen are presented in Table 39. Soil available nitrogen differed significantly due to different fertigation levels with conventional and water soluble fertilizers.

Soil available nitrogen after harvest differed significantly due to different fertigation levels with paired row sowing. The data indicated that paired row sowing with fertigation of 100 per cent RDF (150:75:75 kg ha^{-1}) through conventional fertilizers applied in six equal splits (T_9) recorded significantly higher soil available nitrogen (250.13 kg ha^{-1}) over other treatments.

Table 38: Total potassium uptake (kg ha^{-1}) of Bt cotton as influenced by fertigation levels with conventional and water soluble fertilizers

Treatment	Total potassium uptake (kg ha^{-1})				
	60 DAS	**90 DAS**	**120 DAS**	**150 DAS**	**At harvest**
T_1: Fertigation of 30% RDF through WSF	6.62	39.06	67.48	37.40	26.13
T_2: Fertigation of 25% RDF through WSF	6.04	36.35	62.56	34.44	24.46
T_3: Fertigation of 20% RDF through WSF	5.23	32.76	59.01	31.94	22.80
T_4: Fertigation of 15% RDF through WSF	4.87	28.75	46.28	26.42	19.53
T_5: Fertigation of 25% RDF through CF + T_1	8.85	54.19	85.93	46.03	35.19
T_6: Fertigation of 25% RDF through CF + T_2	8.20	49.49	81.68	44.35	32.15
T_7: Fertigation of 25% RDF through CF + T_3	7.22	45.74	75.34	41.49	30.33
T_8: Fertigation of 25% RDF through CF + T_4	6.84	43.32	70.66	39.39	28.84
T_9: Fertigation of conventional fertilizers with 100 % RDF	9.82	62.77	101.11	55.11	42.76
S. Em. ±	0.26	1.48	3.61	1.55	1.12
C.D. (P=0.05)	0.77	4.44	10.83	4.65	3.34

DAS: Days after sowing, RDF: 150: 75: 75 N: P_2O_5: K_2O kg ha^{-1}, WSF: Water soluble fertilizer (19: 19: 19)

Effect of drip fertigation with only water soluble fertilizers had significant effect on soil available nitrogen. Among treatments involving fertigation with only water soluble fertilizers, paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) applied in six equal splits (T_1) recorded higher soil available nitrogen (221.43 kg ha^{-1}) as compared to other treatments.

Among different treatments involving either fertigation with only water soluble fertilizers or fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers, fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers recorded significant effect on total soil available nitrogen compared to respective fertigation with water soluble fertilizers only. Paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_5) recorded higher soil available nitrogen (234.10 kg ha^{-1}) as compared to others.

4.5.23 Soil available phosphorus

The data on soil available phosphorus at harvest are presented in Table 39. Soil available phosphorus differed significantly due to different fertigation levels with conventional and water soluble of fertilizers.

Soil available phosphorus after harvest differed significantly due to different fertigation levels with paired row sowing. The data indicated that paired row sowing with fertigation of 100 per cent RDF (150:75:75 kg ha^{-1}) through conventional fertilizers applied in six equal splits (T_9) recorded significantly higher soil available phosphorus (29.37 kg ha^{-1}) over other treatments.

Effect of drip fertigation with only water soluble fertilizers had significant effect on soil available phosphorus. Among treatments involving fertigation with only water soluble fertilizers, paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) applied in six equal splits (T_1) recorded higher soil available phosphorus (24.85 kg ha^{-1}) compared to other treatments.

Among different treatments involving either fertigation with only water soluble fertilizers or fertigation with both water soluble fertilizers and 25 per cent RDF through

Table 39: Available soil nutrient status after harvest of Bt cotton as influenced by fertigation levels with conventional and water soluble fertilizers

Treatment	Available soil nutrient status (kg ha^{-1})		
	Available nitrogen (kg ha^{-1})	Available phosphorus (kg ha^{-1})	Available potassium (kg ha^{-1})
T_1: Fertigation of 30% RDF through WSF	221.43	24.85	346.0
T_2: Fertigation of 25% RDF through WSF	216.30	22.66	340.3
T_3: Fertigation of 20% RDF through WSF	211.40	21.47	335.3
T_4: Fertigation of 15% RDF through WSF	209.03	21.07	320.3
T_5: Fertigation of 25% RDF through CF + T_1	234.10	27.43	358.7
T_6: Fertigation of 25% RDF through CF + T_2	233.77	26.87	354.7
T_7: Fertigation of 25% RDF through CF + T_3	231.33	26.34	350.3
T_8: Fertigation of 25% RDF through CF + T_4	228.57	25.84	349.7
T_9: Fertigation of conventional fertilizers with 100 % RDF	250.13	29.37	379.0
S. Em. ±	6.57	1.38	10.1
C.D. (P=0.05)	19.71	4.14	30.2

Initial soil status: 236.8, 27.2, 356.6 kg ha^{-1} available nitrogen, phosphorus and potassium.

conventional fertilizers, fertigation with both water soluble fertilizers and 25 per cent conventional fertilizers recorded significant effect on total soil available phosphorus compared to respective fertigation with water soluble fertilizers only. Paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_5) recorded higher soil available phosphorus (27.43 kg ha^{-1}) as compared to others.

4.5.24 Soil available potassium

The data on soil available potassium after harvest are presented in Table 39. Soil available potassium differed significantly due to different fertigation levels with conventional and water soluble of fertilizers.

Soil available potassium after harvest differed significantly due to different fertigation levels with paired row sowing. The data indicated that paired row sowing with fertigation of 100 per cent RDF (150:75:75 kg ha^{-1}) through conventional fertilizers applied in six equal splits (T_9) recorded significantly higher soil available potassium (379.0 kg ha^{-1}) over other treatments.

Effect of drip fertigation with only water soluble fertilizers had significant effect on soil available potassium. However, paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) applied in six equal splits (T_1) recorded higher soil available potassium (346.0 kg ha^{-1}) compared to other treatments.

Among different treatments involving either fertigation with only water soluble fertilizers or fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers, fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers recorded significant effect on total soil available potassium compared to respective fertigation with water soluble fertilizers only. Paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_5) recorded higher soil available potassium (358.67 kg ha^{-1}) as compared to others.

4.6 Use efficiencies

4.6.1 Nutrient use efficiency

Data pertaining to nutrient use efficiency as influenced by different fertigation levels with different sources of fertilizers are presented in Table 40.

Nutrient use efficiency (NUE) significantly differed due to different levels of fertigation. Paired row sowing with fertigation of 15 per cent RDF (22.5: 11: 11 kg ha^{-1}) through water soluble applied in six equal splits (T_4) had significantly higher NUE (35.56 kg kg^{-1}) over other treatments. However, paired row sowing with fertigation of 100 per cent RDF (150:75:75 kg ha^{-1}) through conventional fertilizers applied in six equal splits (T_9) recorded significantly lower NUE (8.00 kg kg^{-1}).

Among different treatments involving either fertigation with only water soluble fertilizers or fertigation of both water soluble fertilizers and 25 per cent RDF through conventional fertilizers had significant effect on NUE. Treatments involved fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers recorded significantly lower NUE compared to respective fertigation with water soluble fertilizers only.

4.6.2 Nitrogen use efficiency

Influence of different fertigation levels with conventional and water soluble fertilizers had significant effect on nitrogen use efficiency. Significantly higher nitrogen use efficiency was registered at paired row sowing with fertigation of 15 per cent RDF (22.5: 11: 11 kg ha^{-1}) through water soluble applied in six equal splits (T_4) (70.34 kg kg^{-1}) and significantly lower potassium use efficiency was recorded in paired row sowing with fertigation of 100 per cent RDF (150:75:75 kg ha^{-1}) through conventional fertilizers applied in six equal splits (T_9) (16.0 kg kg^{-1}).

4.6.3 Potassium use efficiency

Influence of different fertigation levels with different sources of fertilizers had significant effect on potassium use efficiency. Significantly higher potassium use efficiency was registered at paired row sowing with fertigation of 15 per cent RDF

Table 40: Nutrient use efficiency of Bt cotton as influenced by fertigation levels with conventional and water soluble fertilizers

Treatment	Nutrient use efficiency (kg kg^{-1})		
	Nutrient use efficiency	N use efficiency	K use efficiency
T_1: Fertigation of 30% RDF through WSF	20.59	41.18	82.36
T_2: Fertigation of 25% RDF through WSF	22.96	46.23	91.25
T_3: Fertigation of 20% RDF through WSF	27.80	55.60	111.20
T_4: Fertigation of 15% RDF through WSF	35.56	70.34	143.87
T_5: Fertigation of 25% RDF through CF + T_1	14.12	28.32	56.30
T_6: Fertigation of 25% RDF through CF + T_2	15.03	30.27	59.74
T_7: Fertigation of 25% RDF through CF + T_3	14.77	29.64	56.34
T_8: Fertigation of 25% RDF through CF + T_4	15.84	31.68	62.70
T_9: Fertigation of conventional fertilizers with 100 % RDF	8.00	16.00	32.00
S. Em. ±	1.07	2.14	4.56
C.D. (P=0.05)	3.22	6.42	13.66

DAS: Days after sowing, RDF: 150: 75: 75 N: P_2O_5: K_2O kg ha^{-1}, WSF: Water soluble fertilizer (19: 19: 19)

(22.5: 11: 11 kg ha^{-1}) through water soluble applied in six equal splits (T_4) (143.87 kg kg^{-1}) and significantly lower potassium use efficiency was recorded in paired row sowing with fertigation of 100 per cent RDF (150:75:75 kg ha^{-1}) through conventional fertilizers applied in six equal splits (T_9) (32.00 kg kg^{-1}).

4.7 *Cry* protein expression in leaf

4.7.1 *Cry 1Ac* protein content

The data on *Cry 1Ac* protein content in leaves are presented in Table 41. The results indicated no significant differences among the treatments.

Cry 1Ac protein content in leaves was influenced with each levels of fertigation, but did not differ significantly. Influence of drip fertigation with only water soluble fertilizers had no significant effect on *Cry 1Ac* protein content in leaves. Among different treatments involving either fertigation with only water soluble fertilizers or fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers had no significant effect on *Cry 1Ac* protein content in leaves.

4.7.1 *Cry 2Ab* protein content

The data on *Cry 2Ab* protein content in leaves are presented in Table 42. The results indicated no significant differences among the treatments.

Cry 2Ab protein content in leaves was influenced with each levels of fertigation, but did not differ significantly. Influence of drip fertigation with only water soluble fertilizers had no significant effect on *Cry 2Ab* protein content in leaves. Among different treatments involving either fertigation with only water soluble fertilizers or fertigation with both water soluble fertilizers and 25 per cent RDF through conventional fertilizers had no significant effect on *Cry 2Ab* protein content in leaves.

4.8 Economics

4.8.1 Gross returns

The data pertaining to gross returns are presented in Table 43. Significant differences were observed among treatments.

Table 41: ***Cry 1Ac*** **protein content of Bt cotton as influenced by fertigation levels with conventional and water soluble fertilizers**

Treatment	*Cry 1Ac* protein content (µg g^{-1} fresh weight)				
	45 DAS	60 DAS	90 DAS	120 DAS	150 DAS
T_1: Fertigation of 30% RDF through WSF	2.48	1.88	1.57	1.10	0.64
T_2: Fertigation of 25% RDF through WSF	2.33	1.81	1.48	1.04	0.61
T_3: Fertigation of 20% RDF through WSF	2.33	1.65	1.42	0.90	0.58
T_4: Fertigation of 15% RDF through WSF	2.28	1.64	1.31	0.83	0.55
T_5: Fertigation of 25% RDF through CF + T_1	2.85	2.25	1.91	1.22	0.81
T_6: Fertigation of 25% RDF through CF + T_2	2.81	2.16	1.78	1.18	0.79
T_7: Fertigation of 25% RDF through CF + T_3	2.74	2.15	1.76	1.16	0.73
T_8: Fertigation of 25% RDF through CF + T_4	2.56	2.04	1.65	1.13	0.71
T_9: Fertigation of conventional fertilizers with 100 % RDF	2.95	2.51	1.99	1.40	0.90
S. Em. ±	0.18	0.18	0.15	0.11	0.07
C.D. (P=0.05)	NS	NS	NS	NS	NS

NS: Non significant, DAS: Days after sowing, RDF: 150: 75: 75 N: P_2O_5: K_2O kg ha^{-1}, WSF: Water soluble fertilizer (19: 19: 19)

Table 42: *Cry 2Ab* protein content of Bt cotton as influenced by fertigation levels with conventional and water soluble fertilizers

Treatment	*Cry 2Ab* protein content (µg g^{-1} fresh weight)				
	45 DAS	60 DAS	90 DAS	120 DAS	150 DAS
T_1: Fertigation of 30% RDF through WSF	54.27	45.66	27.74	22.24	13.78
T_2: Fertigation of 25% RDF through WSF	53.83	43.57	27.57	21.48	13.51
T_3: Fertigation of 20% RDF through WSF	53.68	43.11	26.92	21.08	13.21
T_4: Fertigation of 15% RDF through WSF	52.93	41.83	25.77	21.00	12.66
T_5: Fertigation of 25% RDF through CF + T_1	58.94	49.36	30.23	25.93	16.53
T_6: Fertigation of 25% RDF through CF + T_2	58.28	48.06	29.73	24.40	16.64
T_7: Fertigation of 25% RDF through CF + T_3	57.72	46.97	29.46	23.70	15.68
T_8: Fertigation of 25% RDF through CF + T_4	56.28	46.34	28.47	22.80	14.59
T_9: Fertigation of conventional fertilizers with 100 % RDF	60.26	50.63	31.81	26.99	17.76
S. Em. ±	1.67	1.84	1.19	1.35	1.41
C.D. (P=0.05)	NS	NS	NS	NS	NS

NS: Non significant, DAS: Days after sowing, RDF: 150: 75: 75 N: P_2O_5: K_2O kg ha^{-1}, WSF: Water soluble fertilizer (19: 19: 19)

Gross returns increased significantly in paired row sowing with fertigation of 100 per cent RDF (150:75:75 kg ha^{-1}) through conventional fertilizers applied in six equal splits (T_9) (` 2,20,018 $ha^{-1}$) and it was on par with paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg $ha^{-1}$) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits ($T_5$) (` 2,14,170 ha^{-1}) and paired row sowing with fertigation of 25 per cent RDF (37.5: 19: 19 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_6) (` 2,08,083 $ha^{-1}$). Significantly lower gross returns was recorded in paired row sowing with fertigation of 15 per cent RDF (22.5: 11: 11 kg $ha^{-1}$) applied in six equal splits ($T_4$) (` 1,45,072 ha^{-1}).

4.8.2 Net returns

The data pertaining to net returns are presented in Table 43. Significant differences were observed among treatments.

Net returns increased significantly in paired row sowing with fertigation of 100 per cent RDF (150:75:75 kg ha^{-1}) through conventional fertilizers applied in six equal splits (T_9) (` 1,46,115 $ha^{-1}$) and it was on par with paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg $ha^{-1}$) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits ($T_5$) (` 1,34,690 ha^{-1}) and paired row sowing with fertigation of 25 per cent RDF (37.5: 19: 19 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_6) (` 1,31,051 $ha^{-1}$). Significantly lower net returns was recorded in paired row sowing with fertigation of 15 per cent RDF (22.5: 11: 11 kg $ha^{-1}$) applied in six equal splits ($T_4$) (` 79,673 ha^{-1}).

4.8.2 Benefit cost ratio

The data pertaining to benefit cost ratio are presented in Table 43. Significant differences were observed among treatments.

Benefit cost ratio increased significantly in paired row sowing with fertigation of 100 per cent RDF (150:75:75 kg ha^{-1}) through conventional fertilizers applied in six equal splits (T_9) (2.97) and it was on par with paired row sowing with fertigation of 30

Table 43: Economics of Bt cotton as influenced by fertigation levels with conventional and water soluble fertilizers

Treatment	Gross returns (` ha^{-1})	Net returns (` ha^{-1})	B:C
T_1: Fertigation of 30% RDF through WSF	1,69,877	96,290	2.31
T_2: Fertigation of 25% RDF through WSF	1,58,932	88,235	2.24
T_3: Fertigation of 20% RDF through WSF	1,52,900	84,902	2.25
T_4: Fertigation of 15% RDF through WSF	1,45,072	79,673	2.22
T_5: Fertigation of 25% RDF through CF + T_1	2,14,170	1,34,690	2.69
T_6: Fertigation of 25% RDF through CF + T_2	2,08,083	1,31,051	2.70
T_7: Fertigation of 25% RDF through CF + T_3	1,83,407	1,10,769	2.52
T_8: Fertigation of 25% RDF through CF + T_4	1,74,258	1,04,340	2.49
T_9: Fertigation of conventional fertilizers with 100 % RDF	2,20,018	1,46,115	2.97
S. Em. ±	7,412	6,738	0.10
C.D. (P=0.05)	22,221	20,201	0.29

DAS: Days after sowing, RDF: 150: 75: 75 N: P_2O_5: K_2O kg ha^{-1}, WSF: Water soluble fertilizer (19: 19: 19)

per cent RDF (45: 22.5: 22.5 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_5) (2.69) and paired row sowing with fertigation of 25 per cent RDF (37.5: 19: 19 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_6) (2.70). Significantly lower benefit cost ratio was recorded in paired row sowing with fertigation of 15 per cent RDF (22.5: 11: 11 kg ha^{-1}) applied in six equal splits (T_4) (2.22).

5. DISCUSSION

The results obtained from the experiment conducted during *kharif 2016*-17 to study the effect of conventional and water soluble fertilizers through fertigation on growth, yield and quality parameters of Bt cotton are discussed here.

Cotton is an important cash crop in India and 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 more than 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.

Among several factors responsible for crop production, fertilizers and irrigation play an important role. Bt cotton being highly exhaustive crop with regard to plant nutrients, fairly large quantities of nutrients are required. Moisture is one of the important factors for crop production. Because of non judicious method of irrigation, considerable amount of water is being wasted by seepage and deep percolation below the root zone resulting in loss of valuable plant nutrients through leaching. Fertigation has been developed specifically for conditions of intensive crop production. It allows more effective management of fertilizer compared to other methods of fertilizer application. Nutrients are applied to the root zone through fertigation in readily soluble forms where root activity tends to be concentrated to improve the fertilizer use efficiency over broadcast application. Conventional method of fertilizer application to soil results in sub optimal use of precious fertilizers.

5.1 Effect of fertigation level on growth and yield of Bt cotton.

The economic yield of a plant is an outcome of a series of integrated interaction of various biological events involving biochemical, physiological and morphological changes which take place during its development in accordance with the supply of light, water and nutrients. Also, economic yield is a part of the total biological yield of the crop and hence the dry weight production is an important determinant of the economic yield.

In the present investigation the data indicated that seed cotton yield increased significantly with increased levels of fertigation. Fertigation of 100 per cent recommended dose of fertilizer (RDF) recorded significantly higher seed cotton yield (4,000 kg ha^{-1}) over other fertigation levels. However, it was on par with fertigation of 30 per cent RDF through water soluble fertilizers (WSF) along with 25 per cent RDF through conventional fertilizers (CF) (3,894 kg ha^{-1}) and fertigation of 25 per cent RDF through WSF along with 25 per cent RDF through CF (3,783 kg ha^{-1}) (Table 15, Fig.3 and plate 2, 3). The results indicated that, fertigation of both WSF and CF (T_5 and T_6), saved 45 and 50 per cent fertilizer and also recorded on par yield with fertigation of 100 per cent RDF through CF only. The performance of drip fertigation with both WSF and CF was due to application of water and soluble fertilizer at right time, at right place, which resulted in sufficient moisture content and distribution of nutrients in root zone. Root proliferation was greater when the nutrients were applied to root zone resulting in enhanced uptake of nutrients and water. Bhakare *et al.* (2015) reported that higher levels of nutrients through WSF increased the seed cotton yield. Higher seed cotton yield with fertigation of WSF was reported by Baskar and Jagannathan (2014); Nalayini *et al.* (2012) and Pawar *et al.* (2014).

Seed cotton yield increased due to increment of fertigation levels which was attributed to increase in the number of sympodia plant^{-1}, seed cotton yield plant^{-1}, mean boll weight, higher number of good opened bolls plant^{-1}, lower bad bolls plant^{-1} and higher LAI. Fertigation of 100 per cent RDF through CF recorded significantly higher seed cotton yield per plant (275.20 g). However, it was on par with fertigation of 30 per cent RDF through WSF along with 25 per cent RDF through CF (251.43 g) and fertigation of 25 per cent RDF through WSF along with 25 per cent RDF through CF (243.27 g) (Table 15and Fig. 4). It might be due to increased total number of bolls per plant, mean boll weight, higher number of good opened boll per plant and lower bad bolls per plant. Similar response of increased yield per plant was reported by Jayakumar *et al.* (2015), Muthuchamy and Subramanaian (2004) and Bhakare *et al.* (2015) with the application of WSF through drip.

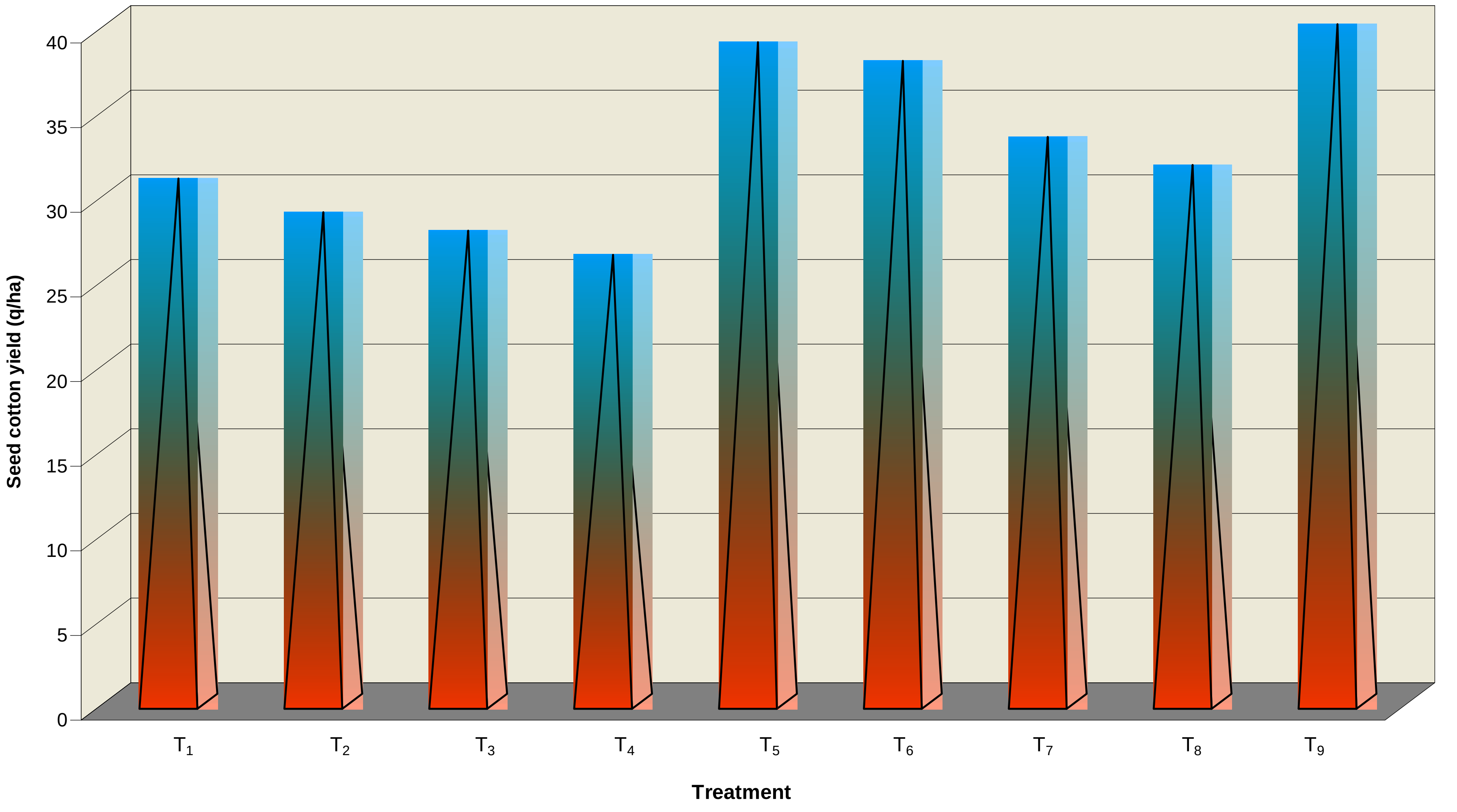

Fig. 3: Seed cotton yield per ha of Bt cotton as influenced by different fertigation levels with conventional and water soluble fertilizers

Drip fertigation with 15 % RDF as WSF

Drip fertigation with 30 % RDF as WSF + 25 % RDF as CF

Drip fertigation with 25 % RDF as WSF + 25 % RDF as CF

Drip fertigation with 100 % RDF as CF

Plate 2: Effect of different drip fertigation levels with CF and WSF on SCY at 150 DAS

Yield per plant is determined by the number of harvested bolls per plant and boll weight. Different fertigation levels were positively correlated with production of number of good open bolls which was directly related with production of seed cotton yield per plant and per hectare. Fertigation of 100 per cent RDF through CF was recorded significantly higher number of good opened bolls plant^{-1} (52.47) which was on par with fertigation of 30 per cent RDF through WSF along with 25 per cent RDF through CF (47.97) (Table 14 and Fig. 5). Another yield component *viz.*, mean boll weight followed similar trend and confirmed higher yield per hectare due to higher levels of nutrients. Boll weight was also an important factor that decides the yield per plant and per hectare. Boll weight, being the function of seed weight and lint weight in a boll, is the direct reflection of extent of photosynthates translocated to bolls. Higher boll weight was recorded with fertigation of 100 per cent RDF through CF applied in six equal splits (6.22 g) compared to other treatments. The favourable effect of fertigation on the physiology of plant through its simulating effects on initiating more boll forming points and their subsequence retention and development in plant leading to higher number of bolls plant^{-1} which must have consequently lead to increase the seed cotton yield plant^{-1} . Jayakumar *et al.* (2015) and Satyanarayana and Janawade (2006) indicated that total bolls per plant and mean boll weight were significantly more in the crop applied with higher levels of nutrients through WSF. Higher fertigation levels increased photosynthetic rate which might have resulted in higher accumulation of metabolites, thus impacted higher boll weight.

The seed cotton yield depends upon the total dry matter production at different stages of crop growth and its partitioning into different parts. Total dry matter production per plant depends on accumulation of dry matter in different plant parts *viz.*, leaf, stem and reproductive parts. During vegetative and early reproductive stages, leaf was the major sink for the photosynthesis, after this phase partitioning of biomass to reproductive parts increased compared to leaf and stem mainly due to number of functional leaves and leaf area plant^{-1} were reduced considerably because of leaf senescence. The total dry matter production was significantly higher with fertigation of 100 per cent RDF through CF at all growth stages except at 30 DAS as compared to

Drip fertigation with 15 % RDF as WSF

Drip fertigation with 30 % RDF as WSF + 25 % RDF as CF

Drip fertigation with 25 % RDF as WSF + 25 % RDF as CF

Drip fertigation with 100 % RDF as CF

Plate 3: Effect of different drip fertigation levels with CF and WSF on SCY at harvest

other treatments and was followed by fertigation of 30 per cent RDF through WSF along with 25 per cent RDF through CF (Table 7 and Fig. 6). Baskar and Jagannathan (2014) indicated that the amount of dry matter production and its distribution into different plant parts depend upon the photosynthetic ability of a plant which in turn depends on leaf, leaf area and duration.

The reason for increase in total dry matter production and its accumulation in different parts of plant are dependent on total photosynthetic area (leaf area index and leaf area duration) and rate of photosynthesis. In the present investigation, leaf area duration and leaf area index (LAI) were greatly influenced by fertigitaion with different sources and levels of nutrients. Fertigation with 100 per cent RDF through CF recorded significantly higher leaf area duration and leaf area index compared to others and was followed by fertigation of 30 per cent RDF through WSF along with 25 per cent RDF through CF. Ayyadurai and Manickasundaram (2014) also stated that fertigation with higher levels of nutrients reported higher leaf area index. Jayakumar *et al.* (2015) indicated that LAI increased slowly in early stages of crop growth and rapidly after seedling stages. As leaf area index increased, light interception was more resulting in higher dry matter production.

Plant height is an important growth factor that governs the seed cotton yield. In the present investigation, fertigation with 100 per cent RDF through CF applied in six equal splits reported higher plant height and was in close proximity with fertigation of 30 per cent RDF through WSF along with 25 per cent RDF through CF. This might be due to increased protoplasmic constituent and acceleration in the process of cell division and there by resulting luxuriant growth. Increased plant height reflected on the increased dry matter production and finally the cotton yield per hectare. Pawar *et al.* (2014), Ayyadurai and Manickasundaram (2014) and Bhakare *et al.* (2015) have also reported increased plant height due to fertigation with higher nutrient levels.

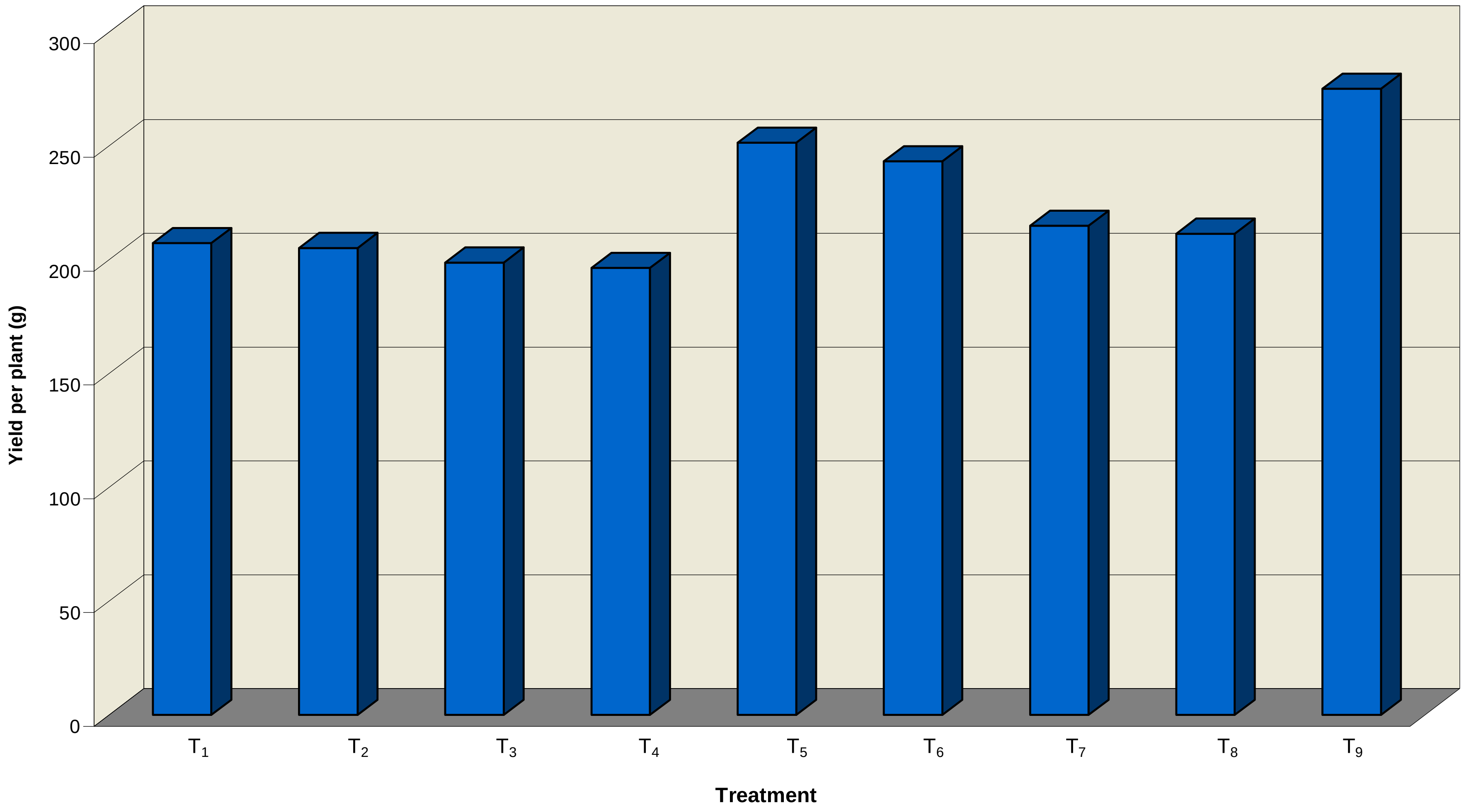

Fig. 4: Seed cotton yield per plant of Bt cotton as influenced by different fertigation levels with conventional and water soluble fertilizers

5.2 Effect of split application of nitrogen and potassium on growth, yield and quality of Bt cotton

5.2.1 Effect of split application of nitrogen and potassium on growth and yield of Bt cotton

Nitrogen which is the most essential nutrient for plant growth needs to be supplied in proper quantities and time. Nitrogen, an integral component of many plant compounds such as amino acids, that are the building blocks of protein, is a vital nutrient for the growth and development of cotton. Its deficiency also leads to reduced plant height, fruiting and increased boll shed. The yield response of Bt cotton and increased *Cry* protein content demands on adequate N fertilization (Pettigrew and Adamczyk, 2006). Potassium (K) is the third major essential plant nutrient along with N and P. Potassium plays a specific role in most of plant species in opening of stomata, increase root growth and improves drought resistance, activities of many enzyme systems, reduce water loss, aids in photosynthesis, respiration and food formation. Nitrogen and Potassium requirement of Bt cotton in the present investigation was met through the split application of various quantities of N and K at equal time interval after sowing and it indicated that seed cotton yield was significantly affected. Data indicated that fertigation of 100 per cent RDF through CF applied in six equal splits recorded significantly higher seed cotton yield and was on par with fertigation of 30 per cent RDF through WSF along with 25 per cent RDF through CF and fertigation of 25 per cent RDF through WSF and 25 per cent RDF through CF. Shruti (2016) also reported that fertigation with six equal splits of N and K resulted in higher seed cotton yield. This was because, nitrogen plays an important role in multiplication of cells and formation of plant parts, which resulted in higher growth of cotton. Cotton being indeterminate crop having long duration, timely supply of N and K under split application has increased sympodial branches, number of bolls, dry matter accumulation per plant which resulted in higher seed cotton yield per plant and per hectare. Similarly yield improvement due to split application of the nutrient was reported by Avudaithai *et al.* (2009), Yadav *et al.* (2014) and Aladakatti *et al.* (2012).

Total dry matter production was significantly influenced by split application of nitrogen and potassium in six equal splits at 15 days interval from 15 DAS to 90 DAS.

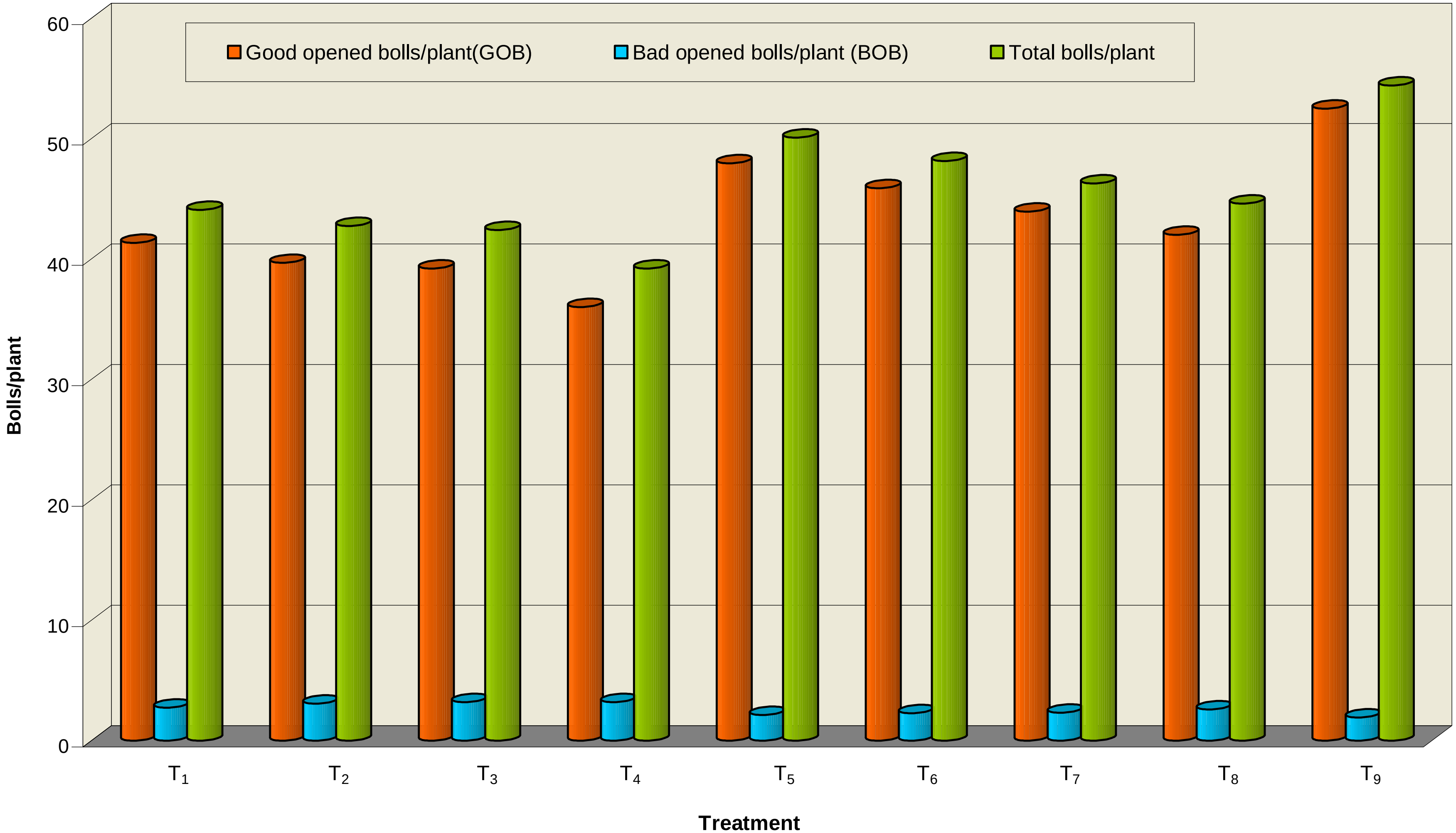

Fig. 5: Good opened bolls, bad opened bolls and total number of bolls per plant of Bt cotton as influenced by fertigation levels with conventional and water soluble fertilizers

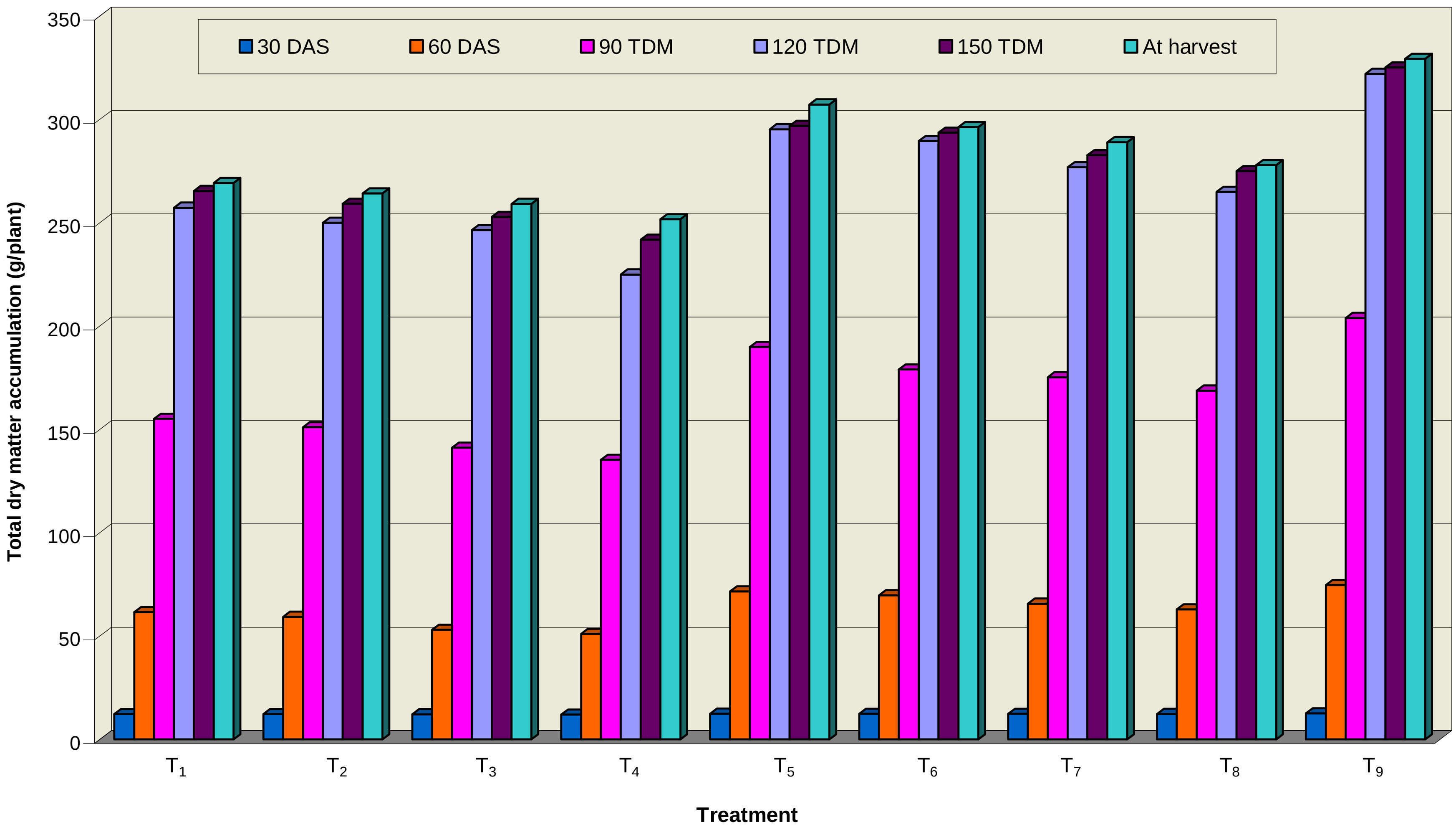

Fig. 6: Total dry matter accumulation of Bt cotton as influenced by fertigation levels with conventional and water soluble fertilizers

Significantly higher dry matter was recorded with fertigation of 100 per cent RDF through CF applied in six equal splits and was followed by fertigation of 30 per cent RDF through WSF along with 25 per cent RDF through CF applied in six equal splits and fertigation of 25 per cent RDF through WSF along with 25 per cent RDF through CF applied in six equal splits. Shruti (2016) and Baskar and Jagannathan (2014) also showed that split application of N and K helped in accumulation of more assimilates in leaves, stem and reproductive parts, thus resulted higher total dry matter production.

The reasons for increased total dry matter production and its accumulation in different parts of plant are dependent on total photosynthetic area (leaf area index and leaf area duration) and rate of photosynthesis. In the present investigation, leaf area index and leaf area duration were increased with split application.

5.2.2 Effect of split application of nitrogen and potassium on cry protein expression

The data indicated that, fertigation of 100 per cent RDF through CF applied in six equal splits recorded higher *Cry 1Ac* protein content in leaf over other fertigation levels at 45, 60, 90, 120 and 150 DAS (2.95, 2.52, 1.99, 1.40 and 0.90 µg g^{-1} fresh weight). However, it was in close proximity with fertigation of 30 per cent RDF through WSF along with 25 per cent RDF through CF applied in six equal splits (2.85, 2.25, 1.91, 1.22 and 0.81 µg g^{-1} fresh weight) and fertigation with 25 per cent RDF through WSF along with 25 per cent RDF through CF applied in six equal splits (2.81, 2.61, 1.78, 1.18 and 0.79 µg g^{-1} fresh weight). Similar trend was followed with respect to *Cry 2Ab* protein content in leaf at 45, 60, 90, 120 and 150 DAS. This might be due to higher leaf nitrogen content and more uptake of nutrient at all the growth stages. Higher amount of *Cry 1Ac* and *Cry 2Ab* protein content in leaf was noticed during initial period (45 DAS) and declining trend was observed during subsequent growth stages and reaching minimum at 150 DAS. It might be due to arrest of proanthocyanin at the later stages, which was the possible cause for decline in endotoxin concentration with maturity (Olsen *et al.,* 2005). Hallikeri *et al.* (2011) reported that application of N in seven splits significantly improved the *Cry* protein level (5,043 ng g^{-1}) over either N applied in 4 splits (4,066 ng g^{-1}) or recommended practice of three splits (3,583 ng g^{-1}).

Drip fertigation with 15 % RDF as WSF

Drip fertigation with 30 % RDF as WSF + 25 % RDF as CF

Drip fertigation with 25 % RDF as WSF + 25 % RDF as CF

Drip fertigation with 100 % RDF as CF

Plate 4: Effect of different drip fertigation levels with CF and WSF on leaf reddening

5.2.3 Effect of split application of nitrogen and potassium on fibre quality

The results showed that fibre quality parameters were not significantly influenced by split application of N and K except for fibre strength. Giri *et al.* (2014), Bhati and Singh (2015) and Shruti (2016) also reported that fibre quality was not affected due to different splits of nitrogen and potassium application.

5.3 Effect of drip fertigation on nutrient content, uptake, nutrient use efficiency and quality of Bt cotton

5.3.1 Effect of drip fertigation on NUE, N and K use efficiency

Drip fertigation levels with WSF and CF had significant effect on nutrient use efficiency. Significantly higher nitrogen and potassium use efficiency was registered in fertigation with 15 per cent RDF through WSF applied in six equal splits over other treatment. Nitrogen use efficiency (70.34 kg kg^{-1}) and potassium use efficiency (143.87 kg kg^{-1}) was significantly higher than other treatments (Table 40 and Fig. 7). Higher nutrient use efficiency might be due to, application of nutrient and water at right time and right place through drip fertigation. This resulted in higher yield with lower nutrient levels. The results are in conformity with Aujla *et al.* (2004) who reported drip fertigation increased seed cotton yield with saving of water and efficient utilization of nutrients, thus impacted higher nutrient use efficiency.

5.3.2 Effect of fertigation level on nutrient content and uptake

In the present investigation, nutrient content and uptake differed significantly at all the growth stages due to different fertigation levels with different sources of fertilizers. The results indicated that fertigation of 100 per cent RDF through CF applied in six equal splits recorded significantly higher nitrogen, phosphorus and potassium content at 60, 90, 120, 150 DAS and at harvest in leaf, stem and reproductive parts and also recorded significantly higher nitrogen, phosphorus and potassium uptake over other treatments. However, it was followed by fertigation of 30 per cent RDF through WSF along with 25 per cent RDF through CF and fertigation of 25 per cent RDF through WSF along with 25 per cent RDF through CF. It might be due to higher dry matter production in different plant parts and nutrient content in plants. These results are in

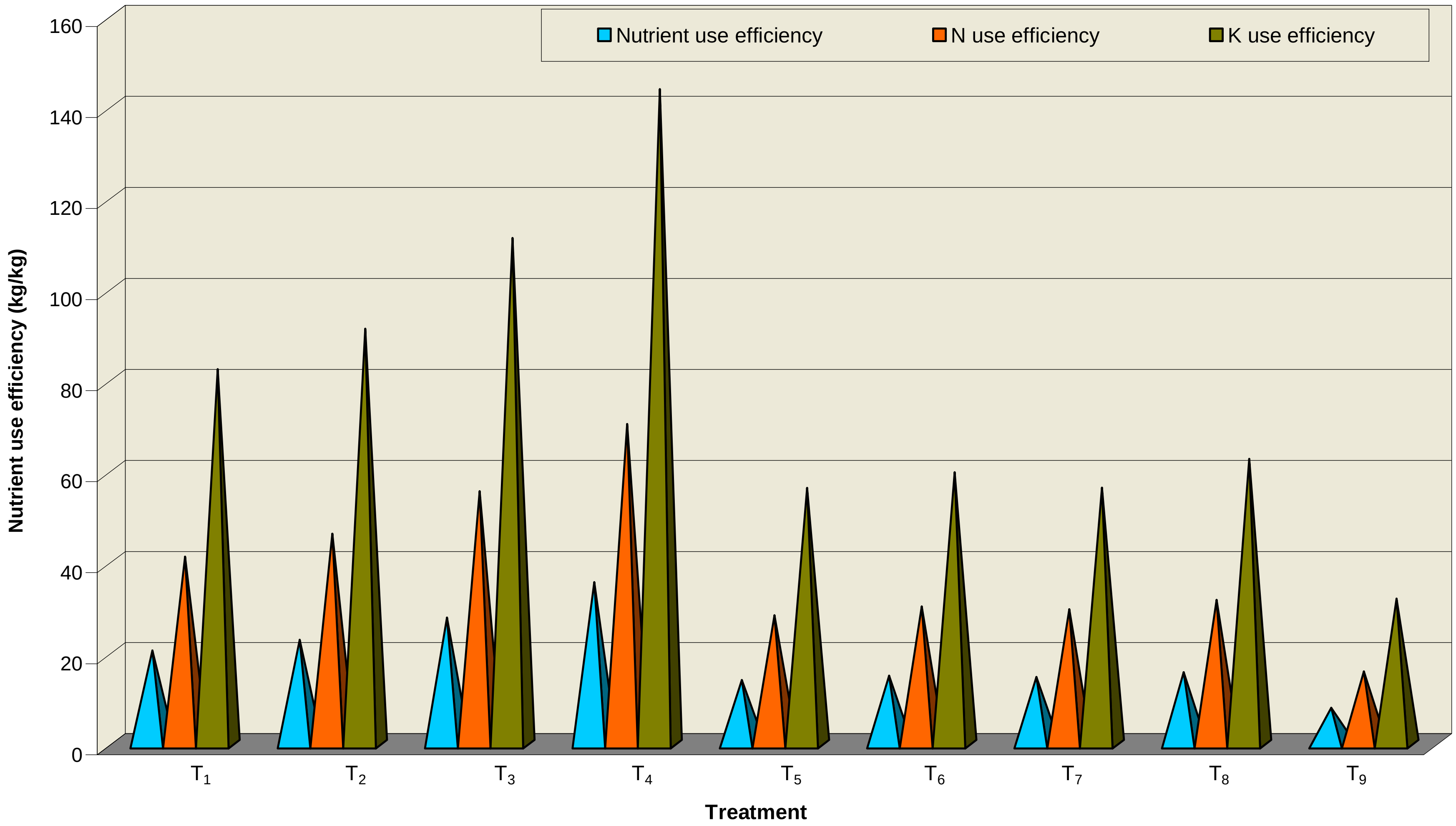

Fig. 7: Nutrient use efficiency of Bt cotton as influenced by fertigation levels with conventional and water soluble fertilizers

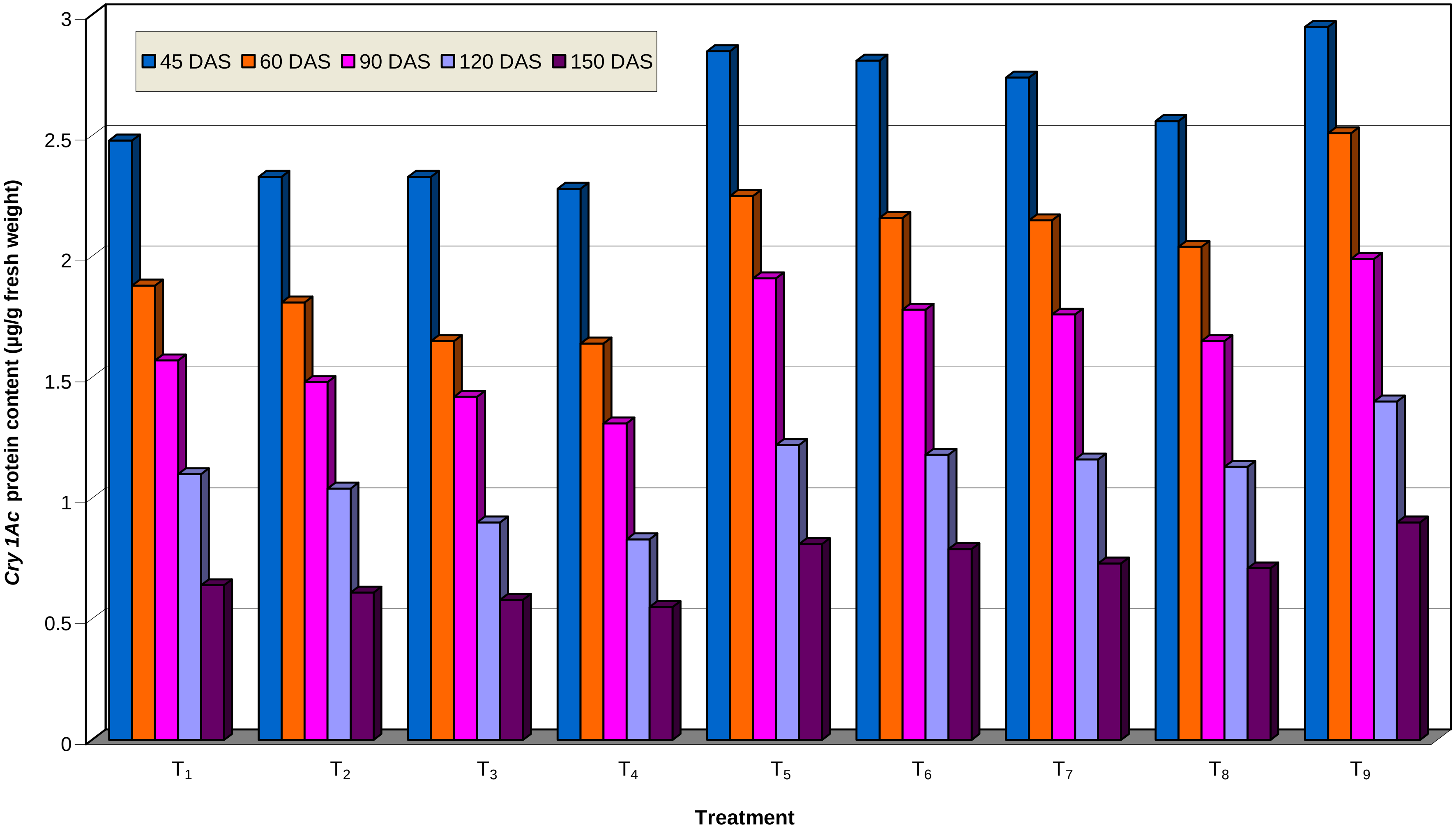

Fig. 8: ***Cry 1Ac*** **protein content of Bt cotton as influenced by fertigation levels with conventional and water soluble fertilizers**

conformity with the findings of Bhalerao *et al.* (2012), Gundlur *et al.* (2013) and Bhakare *et al.* (2015). They reported that, applying higher levels of nutrients significantly increased the dry matter production which resulted in higher uptake of nutrients.

5.3.3 Effect of fertigation level on leaf cry protein concentration and chlorophyll content in leaf

The insecticidal protein content in Bt cotton can be maintained and increased by manipulating crop growth through optimum use of nutrients and moisture levels. Hence, present study was under taken to know the response of Bt cotton to different levels of nutrient management strategies and split application through fertigation with respect to *Cry* protein content, yield and nutrient uptake. Thus, modification of agronomic practices may help in better management of insect pests during the cropping period of Bt cotton to harvest higher yield.

The *Cry 1Ac* and *Cry 2Ab* proteins in leaves was non significant at all the growth stages due to different fertigation levels with different sources of fertilizer. Fertigation with 100 per cent RDF through CF applied in six equal splits recorded higher *Cry 1Ac* and *Cry 2Ab* protein content in leaf at all the growth stages than other treatments. However, it was followed by fertigation of 30 per cent RDF through WSF along with 25 per cent RDF through CF and fertigation of 25 per cent RDF through WSF along with 25 per cent RDF through CF at 45, 60, 90, 120 and 150 DAS. Similar results were reported by Patil (2007) and Basavanneppa (2012) who noticed increased C*ry* protein concentration with application of higher nutrient levels. In the present study, higher C*ry* protein concentration was noticed in initial crop growth stages (45 DAS) and declining trend was observed during subsequent growth stages (Table 41, 42 and Fig. 7, 8). The results are in agreement with the findings of Adamczyk and Summerford (2001), who reported, decline in leaf *Cry* protein concentration as the cotton plants as the growth advanced. At particular stages of crop, *Cry* protein concentration changed with change in the nutrient levels at different crop stages. Studies of Sun *et al.* (2002) and Wan *et al.* (2005) also confirmed the fact that *Cry* protein expression pattern vary with the season with higher concentration at the beginning and least at the end.

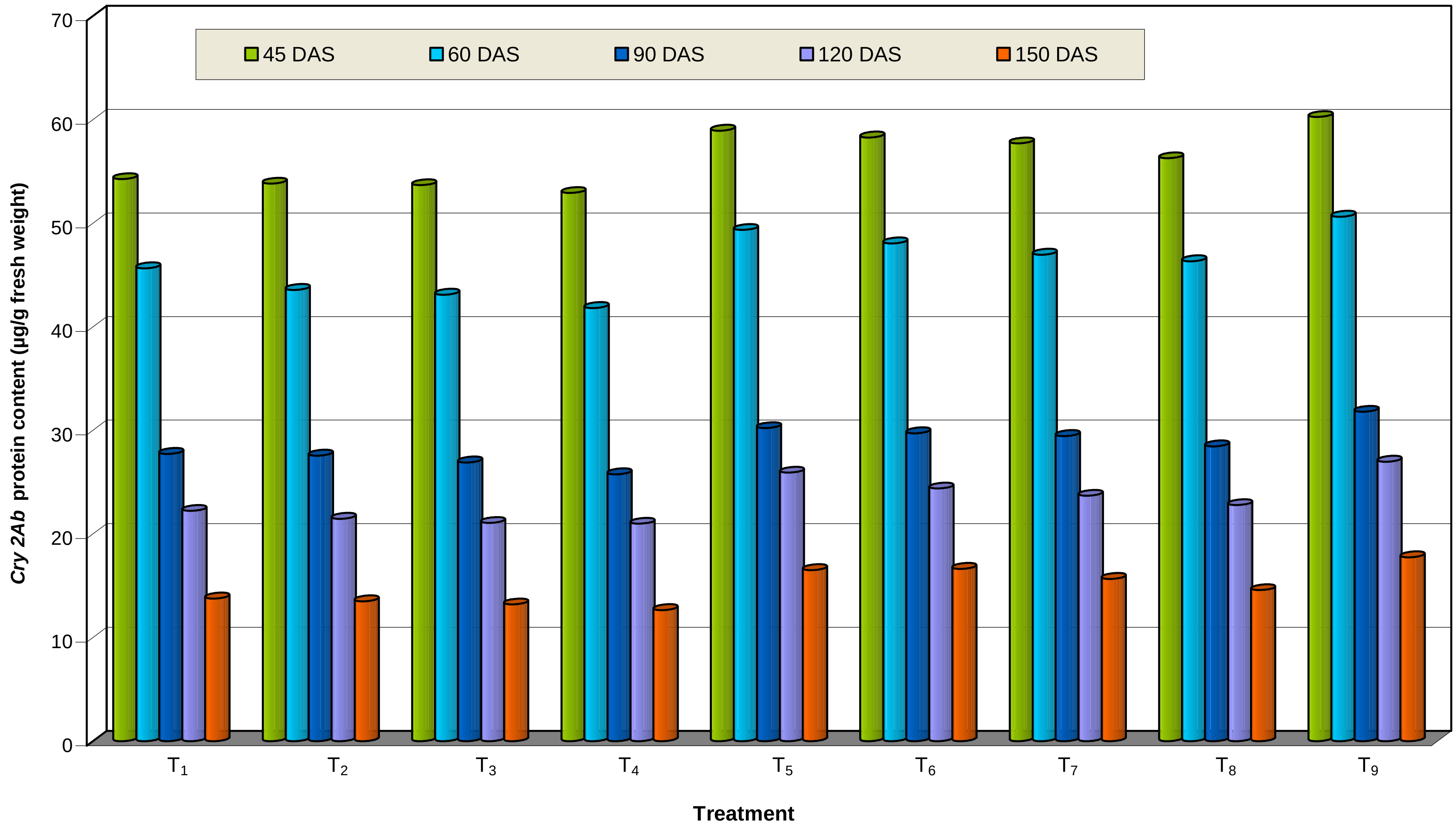

Fig. 9: *Cry 2Ab* protein content of Bt cotton as influenced by fertigation levels with conventional and water soluble fertilizers

Chlorophyll status in leaf is related with the SPAD values. In the present investigation, SPAD values were significantly influenced by fertigation levels. Fertigation of 100 per cent RDF through CF reported significantly higher SPAD values than others at all the growth stages. However, it was on par with fertigation of 30 per cent RDF through WSF along with 25 per cent RDF through CF and fertigation of 25 per cent RDF through WSF along with 25 per cent RDF through CF (Table 10 and plate 4). Brar *et al.* (2002) and Hallikeri *et al.* (2011) indicated that status of chlorophyll content in leaf was affected by nitrogen.

5.3.4 Effect of fertigation levels on fibre quality of Bt cotton

Various fibre quality parameters did not differ significantly through drip fertigation with either water soluble or conventional fertilizers or both except for fibre strength. Bhalerao *et al.* (2011) and Shruti (2016) also reported that fibre quality was not affected due to different fertigation levels.

5.4 Economics

Fertigation of 30 per cent RDF through WSF along with 25 per cent RDF through CF applied in six equal resulted in higher cost of cultivation, over other fertigation levels. This was mainly due to increased cost of water soluble fertilizer and more splits of fertigation. Significantly higher gross return (` 2,20,018 ha$^{-1}$), net returns (` 1,46,115 ha^{-1}) and benefit cost ratio (2.97) was recorded with fertigation of 100 per cent RDF through CF applied in six equal splits (Table 43 and Fig. 10). However, it was on par with fertigation of 30 per cent RDF through WSF along with 25 per cent RDF through CF applied in six equal splits (` 2,14,170 ha$^{-1}$, ` 1,34,690 ha^{-1} and 2.69, respectively) and fertigation of 25 per cent RDF through WSF along with 25 per cent RDF through CF applied in six equal splits (` 2,08,083 ha$^{-1}$, ` 1,31,051 ha^{-1} and 2.7, respectively). This was mainly attributed due to significantly higher seed cotton yield compared to rest of the treatments. Lowest benefit cost ratio was recorded with fertigation of 15 per cent RDF through WSF which was due to lower dose of nutrient supply resulted in lower seed cotton yields. This indicated that fertigation with six equal splits is profitable than soil application. Hence, it is advised to follow drip fertigation of 25 per cent RDF through WSF along with 25 per cent RDF through CF applied in six

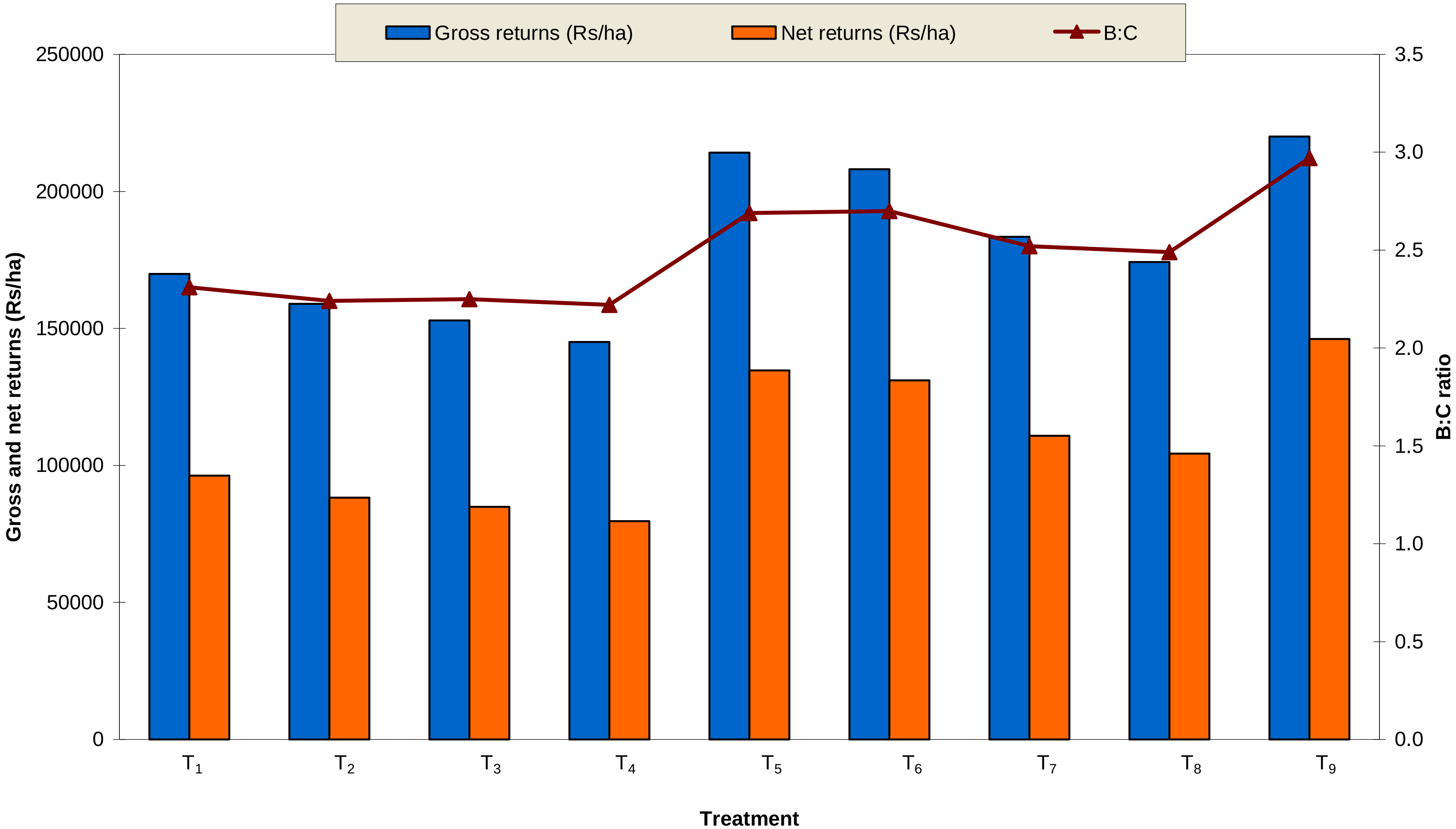

Fig. 10: Economics of Bt cotton as influenced by fertigation levels with conventional and water soluble fertilizers

equal splits at 15 days interval in paired row system of Bt cotton planting where 50 per cent of recommended fertilizers can be saved.

Results of practical utility

The adoption of technology by farmers being the main objective. A technology can be more easily adopted, if the farming community is convinced about its benefits. The results obtained in the present investigation revealed the following practical utilities in promoting the use of drip fertigation with water soluble fertilizer and conventional fertilizer on improving the performance of hybrid Bt cotton in paired row system.

1. Drip fertigation of 25 per cent RDF (37.5: 19: 19 N: P_2O_5: K_2O kg ha^{-1}) through water soluble fertilizers (WSF) (19: 19: 19) along with 25 per cent RDF through conventional fertilizers (CF) (37.5: 19: 19 N: P_2O_5: K_2O kg ha^{-1}) applied in six equal splits found to be optimum for higher seed cotton yield which was on par with the seed cotton yield obtained with 100 per cent RDF through conventional fertilizers (150:75:75 N: P_2O_5: K_2O kg ha^{-1})

2. Fertigation of 25 per cent RDF (37.5: 19: 19 kg ha^{-1}) through WSF along with 25 per cent RDF through CF resulted in higher gross return (` 2,08,083 $ha^{-1}$), net return (` 1,31, 051 ha^{-1}) which was on par with fertigation of 100 per cent RDF through CF (` 2,20,018 $ha^{-1}$ and ` 1,46,115 ha^{-1}, respectively).

3. Fertigation of both WSF along with 25 per cent CF resulted good quality fibre than fertigation of 100 per cent RDF through CF. But superior quality fibre was obtained by fertigation of 30 per cent RDF through WSF

4. Drip fertigation of 25 per cent RDF through WSF along with 25 per cent RDF through CF saved 50 per cent of fertilizer giving same benefit cost ratio as that of 100 per cent RDF.

Future line work

1. Long term effect of fertigation of water soluble fertilizers (WSF) with split application of N and K on soil health and microbes needs to be studied.

2. Effect of drip fertigation with different water soluble fertilizers with N and K split application to hybrid Bt cotton on sequential crops needs to be studied.

3. Drip fertigation with integration of water soluble and organic nutrients on growth and yield of Bt cotton needs to be studied.

6. SUMMARY AND CONCLUSIONS

Field experiment was conducted at Agricultural Research Station, Dharwad farm, Dharwad, Karnataka during the *kharif* 2016-17 to assess the effect of conventional and water soluble fertilizers through fertigation on growth, yield and quality parameters of Bt cotton. The experiment was laid out in randomized complete block design with three replications. The salient findings of the field experiment are summarized as under.

Seed cotton yield differed significantly due to different fertigation levels with conventional and water soluble fertilizers. Paired row sowing with fertigation of 100 per cent RDF (150:75:75 kg ha^{-1}) through conventional fertilizers applied in six equal splits (T_9) recorded significantly higher seed cotton yield (4,000 kg ha^{-1}) over other treatments and it was on par with paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) through water soluble fertilizer along with 25 per cent RDF through conventional fertilizers applied in six equal splits (T_5) (3,894 kg ha^{-1}) and paired row sowing with fertigation of 25 per cent RDF (37.5: 19: 19 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (T_6) (3,783 kg ha^{-1}). Treatment involved paired row sowing with fertigation of 15 per cent RDF (22.5: 11: 11 kg ha^{-1}) applied in six equal splits (T_4) recorded significantly lower seed cotton yield (2,638 kg ha^{-1}).

Leaf area index, leaf area duration and SPAD values varied due to different fertigation levels with conventional and water soluble fertilizers. Paired row sowing with fertigation of 100 per cent RDF (150:75:75 kg ha^{-1}) through conventional fertilizers in six equal splits recorded significantly higher leaf area index, leaf area duration and SPAD values and lower leaf reddening which was on par with paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers in six equal splits.

The *Cry 1Ac* and *Cry 2Ab* protein content in leaves was non significant at all the crop growth stages due to fertigation with conventional and water soluble fertilizers. Fertigation of 100 per cent RDF (150:75:75 kg ha^{-1}) through conventional fertilizers in six equal splits recorded higher *Cry 1Ac* and *Cry 2Ab* protein content over other fertigation levels but total variation in *Cry* protein concentration was non significant

Nutrient uptake differed significantly due to different fertigation levels with conventional and water soluble fertilizers. Fertigation of 100 per cent RDF (150:75:75 kg ha^{-1}) through conventional fertilizers in six equal splits recorded significantly higher nitrogen, phosphorus and potassium uptake in different plant parts compared to other fertigation levels at all the growth stages.

With respect to yield attributes, different fertigation levels of conventional and water soluble fertilizers with six equal split application during plant growth period increased the seed cotton yield per plant, total number harvested bolls and boll weight significantly over the present practice of furrow irrigation with band applications of fertilizers. Fertigation of 100 per cent RDF (150:75:75 kg ha^{-1}) through conventional fertilizers in six equal splits recorded significantly higher seed cotton yield per plant (275.20 g), total number harvested bolls (54.40 $plant^{-1}$), boll weight (6.22 g), which was on par with paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) through water soluble fertilizer along with 25 per cent RDF through conventional fertilizers applied in six equal splits and paired row sowing with fertigation of 25 per cent RDF (37.5: 19: 19 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits.

Growth parameters varied significantly with respect to fertigation levels with conventional and water soluble fertilizers with six equal split application. Paired row sowing with fertigation of 100 per cent RDF (150:75:75 kg ha^{-1}) through conventional fertilizers in six equal splits recorded significantly higher leaf area index, leaf area duration, SPAD and lower leaf reddening at all the growth stages and was on par with paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) through water soluble fertilizer along with 25 per cent RDF through conventional fertilizers applied in six equal splits. Drip fertigation of 100 per cent RDF (150:75:75 kg ha^{-1}) through conventional fertilizers recorded significantly higher total dry matter accumulation and its partitioning *viz.*, dry matter production in leaf, stem and in reproductive parts at 60, 90 120, 150 DAS and at harvest over other treatments. However it was on par with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1})

through water soluble fertilizer along with 25 per cent RDF through conventional fertilizers at 60, 90 120 and at harvest.

Fibre quality parameters were not significantly differed due to different fertigation levels with conventional and water soluble fertilizers. Drip fertigation of 100 per cent RDF (150:75:75 kg ha^{-1}) through conventional fertilizers recorded higher seed index, ginning out turn and lint index compared to other fertigation levels. Fertigation with only water soluble fertilizers or both water soluble and conventional fertilizers resulted in good quality fibre than that of conventional fertilizers only.

Drip fertigation of 15 per cent RDF (22.5: 11: 11 kg ha^{-1}) through WSF applied in six equal splits recorded significantly higher nutrient use efficiency (35.56 kg kg^{-1}) over other treatments. However, paired row sowing with fertigation of 100 per cent RDF (150:75:75 kg ha^{-1}) through conventional fertilizers applied in six equal splits recorded significantly lower nutrient use efficiency (8.00 kg kg^{-1}).

Influence of different fertigation levels with conventional and water soluble fertilizers had significant effect on nitrogen use efficiency. Significantly higher nitrogen and potassium use efficiency was registered with T_4 (70.34 and 143.87 kg kg^{-1}, respectively).

Among different fertigation levels with conventional and water soluble fertilizers, paired row sowing with fertigation of 100 per cent RDF (150:75:75 kg ha^{-1}) through conventional fertilizers applied in six equal splits recorded significantly higher gross returns (` 2,20,018 $ha^{-1}$), net returns (` 1,46,115 ha^{-1}) and B:C (2.97). It was on par with paired row sowing with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) through water soluble fertilizer along with 25 per cent RDF through conventional fertilizers applied in six equal splits (` 2,14,170 $ha^{-1}$, ` 1,34,690 ha^{-1} and 2.69, respectively) and paired row sowing with fertigation of 25 per cent RDF (37.5: 19: 19 kg ha^{-1}) through water soluble fertilizer and 25 per cent RDF through conventional fertilizers applied in six equal splits (` 2,08,083 $ha^{-1}$, ` 1,31,051 ha^{-1} and 2.70, respectively).

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Appendix I: Prices of inputs and outputs

Items		Units	Price (`)
Seed	Ajit 115 (BG II)	450 g	800
Fertilizers	19: 19: 19	50 kg	5000
	Urea	50 kg	300
	SSP	50 kg	420
	MOP	50 kg	600
Manure	FYM	tonne	500
Pesticides	Regent	l	1200
	Acephate	kg	750
	Proclaim	500 g	3650
	Polo	250 g	880
	Contaf	l	560
	Curacron	l	900
	DDVP	l	600
Labours	Men	Day	157
	Women	Day	157
	Bullock pair	Day	500
Others	Tractor (ploughing)	Day	1500
	Transporting	Day	1000
	Picking cost	kg	5
Output	Seed cotton selling price	Qtl	5500

Appendix II: Details of cost of cultivation in different treatments

Particulars	T_1	T_2	T_3	T_4	T_5	T_6	T_7	T_8	T_9
Ploughing	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500	1,500
Labour	11,775	11,775	11,775	11,775	11,775	11,775	11,775	11,775	11,775
Harrowing	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000	4,000
Sowing	1,256	1,256	1,256	1,256	1,256	1,256	1,256	1,256	1,256
Seed cost	4,400	4,400	4,400	4,400	4,400	4,400	4,400	4,400	4,400
FYM	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000	5,000
All19	11,842	10,000	7,895	6,053	11,842	10,000	7,895	6,053	0
Urea	293	241	196	150	783	730	685	639	1957
SSP	0	0	0	0	998	998	998	998	3938
MOP	0	0	0	0	380	380	380	380	1500
Hand weeding and Intercultivation	6,025	6,025	6,025	6,025	6,025	6,025	6,025	6,025	6,025
Pesticides	10,051	10,051	10,051	10,051	10,051	10,051	10,051	10,051	10,051
Picking cost	15,443	14,448	13,900	13,188.3	19,470	18,916.7	16,673.3	15,841.7	20,001.7
Transport	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Cleaning and packaging	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000	1,000
Total expenditure	73,586	70,697	67,998	65,398	79,480	77,032	72,638	69,918	73,903

T_1: Fertigation of 30% RDF through water soluble fertilizer (WSF)
T_2: Fertigation of 25% RDF through WSF
T_3: Fertigation of 20% RDF through WSF
T_4: Fertigation of 15% RDF through WSF
T_5: Fertigation of 25% RDF through Conventional fertilizer (CF) + T_1
T_6: Fertigation of 25% RDF through CF + T_2
T_7: Fertigation of 25% RDF through CF + T_3
T_8: Fertigation of 25% RDF through CF + T_4
T_9: Fertigation of conventional fertilizers with 100 % RDF

EFFECT OF CONVENTIONAL AND WATER SOLUBLE FERTILIZERS THROUGH FERTIGATION ON GROWTH, YIELD AND QUALITY PARAMETERS OF Bt COTTON

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ABSTRACT

A field experiment was undertaken to study the effect of fertigation levels with conventional and water soluble fertilizers on growth, yield and quality of Bt cotton at the Agricultural Research Station, Dharwad, Karnataka during the *kharif* 2016-17 with nine treatments replicated thrice in a randomized complete block design. Paired row sowing (PS) with fertigation of 100 per cent RDF (150:75:75 kg ha^{-1}) through conventional fertilizers (CF) applied in six equal splits recorded significantly higher number of bolls $plant^{-1}$ (54.40) and seed cotton yield ha^{-1} (4,000 kg ha^{-1}) than other treatments, but was on par with PS with fertigation of 30 per cent RDF (45: 22.5: 22.5 kg ha^{-1}) through water soluble fertilizer (WSF) and 25 per cent RDF through CF applied in six equal splits (50.1 and 3,894 kg ha^{-1}), PS with fertigation of 25 per cent RDF (37.5: 19: 19 kg ha^{-1}) through WSF and 25 per cent RDF through CF applied in six equal splits (48.13 and 3,783 kg ha^{-1}). Significantly lower bolls $plant^{-1}$ (39.20) and seed cotton yield ha^{-1} (2,638 kg ha^{-1}) were recorded in PS with fertigation of 15 per cent RDF (22.5: 11: 11 kg ha^{-1}) applied in six equal splits. Fiber quality parameters of Bt cotton did not differ significantly due to fertigation levels with CF or WSF except for fiber strength. PS with fertigation of 30 per cent RDF through WSF applied in six equal splits recorded higher fiber strength (28.03 g tex^{-1}) as compared to other treatments. The *Cry 1Ac* and *Cry 2Ab* protein content in leaves was non-significant at all the growth stages with varied levels of fertigation. The highest net returns (Rs. 1,46,115 ha^{-1}) and benefit cost ratio (2.97) were recorded in PS with fertigation of 100 per cent RDF (150:75:75 kg ha^{-1}) through CF applied in six equal splits which were on par with PS with fertigation of 25 per cent RDF through WSF and 25 per cent RDF through CF applied in six equal splits.