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COMPARATIVE ANALYSIS OF FOLIAR SPRAYS AND IRRIGATION REGIMES ON GROWTH, PHYSIOLOGICAL ATTRIBUTES AND YIELD OF Bt COTTON (*GOSSYPIUM HIRSUTUM* L.)

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ABSTRACT

The investigation, conducted during the June–Feb 2012 at the Department of Agricultural Botany, Dr. PDKV Akola, Maharashtra, India utilized a randomized block design with three replications to study "the comparative analysis of foliar spraying and irrigation regimes on growth, physiological attributes and yield of Bt Cotton (*Gossypium hirsutum* L.)." The study examined the effects of foliar fertilizers *i.e.*, T_1-NPK Spray (10:5:5 kg ha^{-1}), T_2-AA (500 ppm l^{-1}), T_3-PMA (10 ppm l^{-1}), T_4-Cycocel (500 ppm l^{-1}), T_5-Kinetin (10 ppm l^{-1}), T_6- AA + PMA (500 ppm l^{-1}), T_7-$MgSO_4$ spray (0.5%), T_8-$MgSO_4$ spray (1%), T_9-Micro-nutrients (1ml l^{-1}), T_{10}-DAP (2%), T_{11}-GA_3 (50 ppm l^{-1}), T_{12}-KNO3 (1%), T_{13}-Control (No spray). T_{14}-Irrigation at critical stages (flowering and boll development) and T_{15}- Urea (2%) on various parameters of cotton production, including plant height, leaf area plant^{-1}, leaf area index, chlorophyll content index, total dry matter production, red leaf incidence, yield and yield contributing character. Results from the study indicated that applying foliar sprays containing $MgSO_4$ spray at 1% notably increased plant height, leaf area, total dry matter and chlorophyll content index. Additionally, it reduced red leaf incidence and increased cotton yield and yield attributes compared to control plants as well as treatment involves DAP, Urea and Cycocel showing better results in yield contributing characters like number of bolls plant^{-1}, boll weight and seed cotton production. The findings of the study suggest that foliar application of $MgSO_4$ at 1% can effectively enhance the growth, physiological attributes and yield of Bt cotton.

Key words : Bt cotton, Plant growth regulators, Nutrients, Growth and Physiology, Yield.

Introduction

Cotton (*Gossypium* spp.) is a dual-purpose crop that is cultivated for both fibre and oil (Ali *et al*., 2019); for this reason, it is known as the "king of fibbers" and one of the most significant textile crops in the world. According to Hou *et al*. (2018), the most widely farmed type of cotton is upland cotton, which produces 95% of the crop annually in the globe. Its dominance over other cash crops in India explains its importance to the country's economy (Rothe and Kshirsagar, 2014).

In India, cotton (*Gossypium herbaceum* L.) is one of the most important commercial crops and is generally known as white gold, which account world's second-largest producer of cotton, with an annual production of around 6 million bales (Rothe and Kshirsagar, 2014). Also, India is only country in the world to produce all four cultivated species along with some of their hybrid varieties. The diversity of cotton cultivars and cotton agroclimatic zones in India are considerably larger when compared to other major cotton producing countries in the world. The most important reason for the adoption of Bt cotton (a genetically modified variety) in India was the reduction in the use of pesticides, which accounted for about 45% of the total pesticide consumption in the country (Qaim and Kouser, 2013).

Foliar spraying and irrigation at key stages can improve yield contributing traits such as number of bolls plant^{-1} and seed cotton yield plant^{-1} in cotton crops, as well as morpho-physiological parameters such as plant growth, plant height, leaf area, leaf area index and total dry matter production (Divya *et al*., 2022). Additionally, they are essential for a number of growth activities, such as cell elongation and division. When irrigation is applied at important periods of plant population growth, various foliar sprays have diverse results (Meena *et al*., 2017; Abeed *et al*., 2021; Divya *et al*., 2022; Lowry *et al*., 1951). The problem of magnesium insufficiency in cotton, which causes red leaf disease and drastically lowers production, can be lessened by applying liquid multinutrient fertiliser and applying magnesium sulphate foliar nutrition. Research has indicated that the administration of magnesium and zinc topically can enhance grape cultivars' productivity and quality attributes, including juice, pH, acidity and total soluble solids (Bybordi and Shabanov, 2010). Foliar sprays have a significant impact on how cotton grows and behaves physiologically. Including foliar application in fertilisation strategy optimisation increases fertiliser usage efficiency and lowers environmental contamination (Radhika *et al*., 2013). Furthermore, it has been discovered that foliar applications of magnesium also significantly increase dry matter accumulation and improve overall plant vigour, which leads to better yield outcomes in a variety of crops, such as grapes and cotton (Bybordi and Shabanov, 2010; Altarugio *et al*., 2017).

Farmers these days are perplexed about the appropriate foliar spray (fertiliser) kind, concentration and impact. Choosing the best foliar spray for a given crop and set of circumstances can be difficult due to the variety of products available. Farmers must determine if the expenditure is justified by the increased production or quality gains from foliar treatments. Without precise, fact-based information, this evaluation may be challenging. Consequently, in order to minimize losses in the development, production and economics of Bt cotton, research must be done on the relative effects of foliar sprays and irrigation regimes on the growth, physiological characteristics, and yield of Bt cotton.

Materials and Methods

Field experiment was conducted at research field of Department of Agricultural Botany, Dr. Panjabrao Deshmukh Krishi Vidyapeeth, Akola, Maharashtra, India located at 304.415-meter altitude, 20^{0}30' N latitude and 72^{o}02' longitude during *kharif* season (June–Feb) of 2011, in randomized block design with three replications. Sowing is done in net plot 3.6×2.6 m with plant spacing 90 x 30 cm^2. The variety RCH-2 BG II was spraying with the different growth components *viz*. T_1- NPK Spray (10:5:5 kg ha^{-1}), T_2- Ascorbic Acid (AA) (500 ppm l^{-1}), T_3- Phenol Mercuric acetate (PMA) (10 ppm l^{-1}), T_4- Cycocel (500 ppm l^{-1}), T_5- Kinetin (10 ppm l^{-1}), T_6- AA+PMA (500 ppm l^{-1}), T_7- $MgSo_4$ spray (0.5%), T_8- $MgSo_4$ spray (1%), T_9- Micro-nutrients- Hoagland solution (1ml l^{-1}), T_{10}- DAP (2%), T_{11}- GA_3 (50 ppm l^{-1}), T_{12}- KNO_3 (1%), T_{13}- Control (No spray). T_{14}- Irrigation at critical stages (flowering and boll development) and T_{15}- Urea (2%). Treatment (Spraying) schedule should be undertaken at 60 DAS.

The observations of various morpho-physiological and yield contributing parameters were recorded as randomly selected plants from each net plot. The data analyzed as per procedure illustrated by Panse and Sukhatme (1985).

Results and Discussion

Plant height (cm)

Plant height was greatly impacted by the various treatments at 110 DAS, as Table 1 and Fig. 1(a) demonstrate. Out of all the treatments, treatment T_8 (104.33 cm) recorded the highest plant height compared to control; however, the remaining treatments were found to be on par with T_{15} (103.33 cm) and T_3 (101.66 cm). Treatment T_4 (CCC spray @ 500 ppm) recorded the lowest plant height (89.66 cm). Also shown to be on par with treatment T_8 were treatments T_1, T_5, T_6, T_7, T_{10}, T_{11} and T_{14}.

The application of nitrogen, phosphorus, and potassium can significantly influence the plant growth and development of cotton plants, as evident from previous studies (Bednarz *et al*., 1998). The application of GA_3 and Cycocel had a significant effect on plant height (Akram *et al*., 2017 and Kulvar Singh *et al*., 2015).

Leaf area plant^{-1} (dm^2)

Plant assimilatory surface, assessed in terms of LA (dm^2) across various treatments, was shown to be significant at 110 DAS, as Table 1 and Fig. 1(a) illustrate. In comparison to treatment T_7 (76.49 dm^2) and treatment T_{14} (75.24 dm^2), treatment T_8 ($MgSO_4$ spray @1%) recorded a significantly higher leaf area plant^{-1} (79.45 dm^2). On the other hand, treatment T_4 (CCC spray @500 ppm) recorded the lowest leaf area plant^{-1} (69.14 dm^2) of all the treatments, and was found to be on par with control and most of the treatments. Leaf area (dm^2 plant-

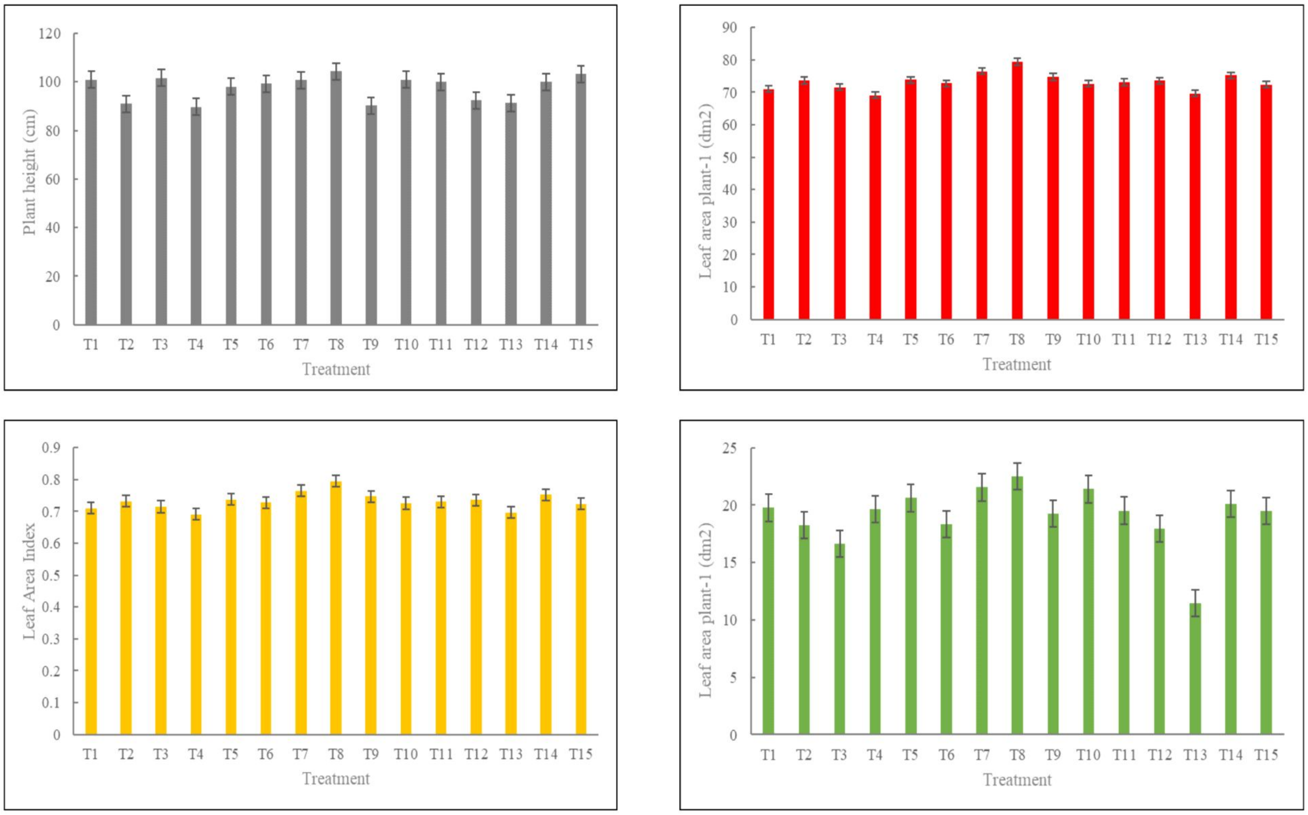

Fig. 1(a) : Effects of Foliar sprays and Irrigation strategies on growth, physiological traits and yield of Bt cotton (*Gossypium hirsutum* L.). **Note:** T_1- NPK spray (10:5:5 kg ha^{-1}), T_2- Ascorbic acid spray @500 ppm, T_3- PMA spray @10 ppm, T_4- CCC spray @ 500 ppm, T_5- Kinetin spray @10 ppm, T_6- AA+PMA spray @500 ppm (1:1), T_7- $MgSO_4$ spray @0.5%, T_8- $MgSO_4$ spray @ 1%, T_9- Micro nutrients (Hoagland solution) spray @1 ml L^{-1}, T_{10}- DAP spray @2%, T_{11}- GA_3 spray 50 ppm, T_{12}- KNO_3 spray @ 1%, T_{13}- Control (No spray), T_{14}- Irrigation at critical stages (flowering and boll development), T_{15}- Urea spray @ 2%.

^{1}) was considerably highest when $MgSO_4$ (spray @ 1%) was applied.

Increase in leaf area was associated with increase in number of leaves plant^{-1} and developed canopy structure which provide maximum photosynthesis for growth and development of cotton plant. Several studies have reported that the foliar application of nutrients and growth regulators, such as Cycocel, can enhance the leaf area of plants (Akram *et al*., 2017; Liza *et al*., 2021; Prakash *et al.*, 2001).

Leaf area index

As illustrated in Table 1 and Fig. 1(a) Treatment T_8 ($MgSo_4$ spray @1%) at 110 DAS recorded a leaf area index that was much greater than the control and the other treatments, although it was still on par with T_7 and T_{14}. Treatment T_8 ($MgSO_4$ spray @1%) was shown to be superior in the current experiment for preserving greater LAI, with T_7 and T_{14} following suit.

This is in accordance with the reports that the foliar application of magnesium and boron can increase leaf area and leaf area index of cotton plants (Bednarz *et al*., 1998).

Chlorophyll content index (CCI)

The CCI data of cotton plants at various days after sowing was determined to be statistically significant at 100 DAS, as Table 1 and Fig. 1(a) illustrate. Treatment T_8 ($MgSo_4$ spray @1%) recorded the greatest CCI (22.50) compared to the control, while treatment T_{13} (Control-no spray) recorded the lowest CCI (11.46) among all treatments. All treatments recorded substantially greater CCIs than the control. As for the treatments, T_8, T_1, T_4, T_5, T_7, T_9, T_{10}, T_{11}, T_{14} and T_{15} were determined to be on par with each other and to have effects that were quite similar.

The foliar application of $MgSO_4$, DAP, urea significantly higher CCI. Magnesium is a constituent of chlorophyll, which is necessary for photosynthesis and also Sulphur increases chlorophyll content of leaf, which has nitrogen as a main constituent. Nitrogen is an integral part of chlorophyll manufacture through photosynthesis. Similar results were also recorded by Bednarz *et al*. (1998), Khader and Prakash (2007), Ramesh and

Table 1 : Effects of Foliar sprays and Irrigation strategies on Growth, Physiological Traits and Yield of Bt Cotton (*Gossypium hirsutum* L).

Treatment	Plant height (cm) at 110 DAS	Leaf area plant^{-1} (dm^2) at 110 DAS	Leaf area index at 110 DAS	Chlorophyll content index at 100 DAS	Total dry matter production at 120 DAS	No. of bolls plant^{-1} at 120 DAS	Red leaf incidence (%) at 120 DAS	Seed cotton yield (g plant^{-1})
T_1	101.00*	71.01	0.710*	19.78*	76.61	22.44*	27.33	63.55*
T_2	91.00	73.72	0.732	18.25	76.82	21.64	28.00	61.26
T_3	101.66	71.54	0.715	16.63	72.32	21.72	28.33	61.53
T_4	89.66	69.14	0.691*	19.65*	69.54	22.97*	30.00	65.12*
T_5	98.00*	73.83	0.738*	20.63*	74.75	21.91	28.33	62.09
T_6	99.33*	72.78	0.728	18.33	73.03	21.85	29.00	61.99
T_7	100.66*	76.49*	0.765*	21.56*	77.38	23.03*	29.33	65.33*
T_8	104.33	79.45	0.795	22.50	77.52	24.00*	25.00	67.98*
T_9	90.33	74.73	0.747*	19.26*	74.73	22.14	27.33	62.75
T_{10}	101.00*	72.63	0.726*	21.40*	76.25	25.25	24.33	71.50
T_{11}	100.00*	73.10	0.731*	19.53*	74.22	20.82	28.33	59.03
T_{12}	92.33	73.59	0.736	17.96	73.79	20.80	29.33	59.03
T_{13}	91.33	69.65	0.697	11.46	69.04	19.11	31.33	54.79
T_{14}	100.00	75.24*	0.752*	20.10*	77.18	24.64*	27.66	69.72*
T_{15}	103.33	72.38	0.724*	19.50*	77.03	24.22*	25.66	69.94*
F test	S	S	S	S	S	S	S	S
SE (m)	3.44	1.812	0.018	1.182	1.316	1.06	1.178	2.967
CD 5%	9.990	5.248	0.052	3.425	3.814	3.07	3.412	8.593

*Indicates at par with highest value.

Note: T_1- NPK spray (10:5:5 kg ha^{-1}), T_2- Ascorbic acid spray @500 ppm, T_3- PMA spray @10 ppm, T_4-CCC spray @ 500 ppm, T_5- Kinetin spray @10 ppm, T_6- AA+PMA spray @500 ppm (1:1), T_7- $MgSO_4$ spray @0.5%, T_8- $MgSO_4$ spray @ 1%, T_9- Micro nutrients (Hoagland solution) spray @1 ml L^{-1}, T_{10}- DAP spray @2%, T_{11}- GA_3 spray 50 ppm, T_{12}- KNO_3 spray @ 1%, T_{13}- Control (No spray), T_{14}- Irrigation at critical stages (flowering and boll development), T_{15}- Urea spray @ 2%.

Ramprasad (2014).

Total dry matter production (g plant^{-1})

The variations in dry matter production among the different treatments were found to be substantial at 120 DAS, as Table 1 and Fig. 1(b) illustrate. Every treatment, with the exception of T_3 and T_4, produced noticeably more dry matter than the control. Of all the treatments, treatment T_8 produced the highest dry matter (77.52 g plant^{-1}), whereas treatment T_{13}-control produced the lowest (69.04 g plant^{-1}), albeit it was still comparable to treatments T_3 and T_4.

The foliar application of $MgSO_4$ (1%), DAP (2%) and Urea (2%) at different days after sowing as well as irrigation at critical growth stages (flowering and boll development) recorded higher dry matter accumulation. The positive effect of Mg on dry biomass accumulation and plant height might be attributed to its role in photosynthesis, as a carrier of phosphorus, improvement of nutrient uptake, sugar synthesis and starch translocation. Similar results were also recorded by Delfani *et al.* (2014).

Red leaf incidence (%)

According to Table 1 and Fig. 1(b), at 120 DAS, the results showed that the incidence of red leaves on cotton plants was statistically significant. Out of all the treatments, treatment T_{13} (Control) had the greatest red leaf incidence (31.33%), whereas treatment T_{10} (DAP spray @ 2%) had the considerably lowest red leaf incidence (24.33%) compared to control. Treatments T_8, T_{15}, T_1, T_9 and T_{14} were the next in line. Treatment T_{10} was shown to be comparable to treatments T_1, T_8, T_9,

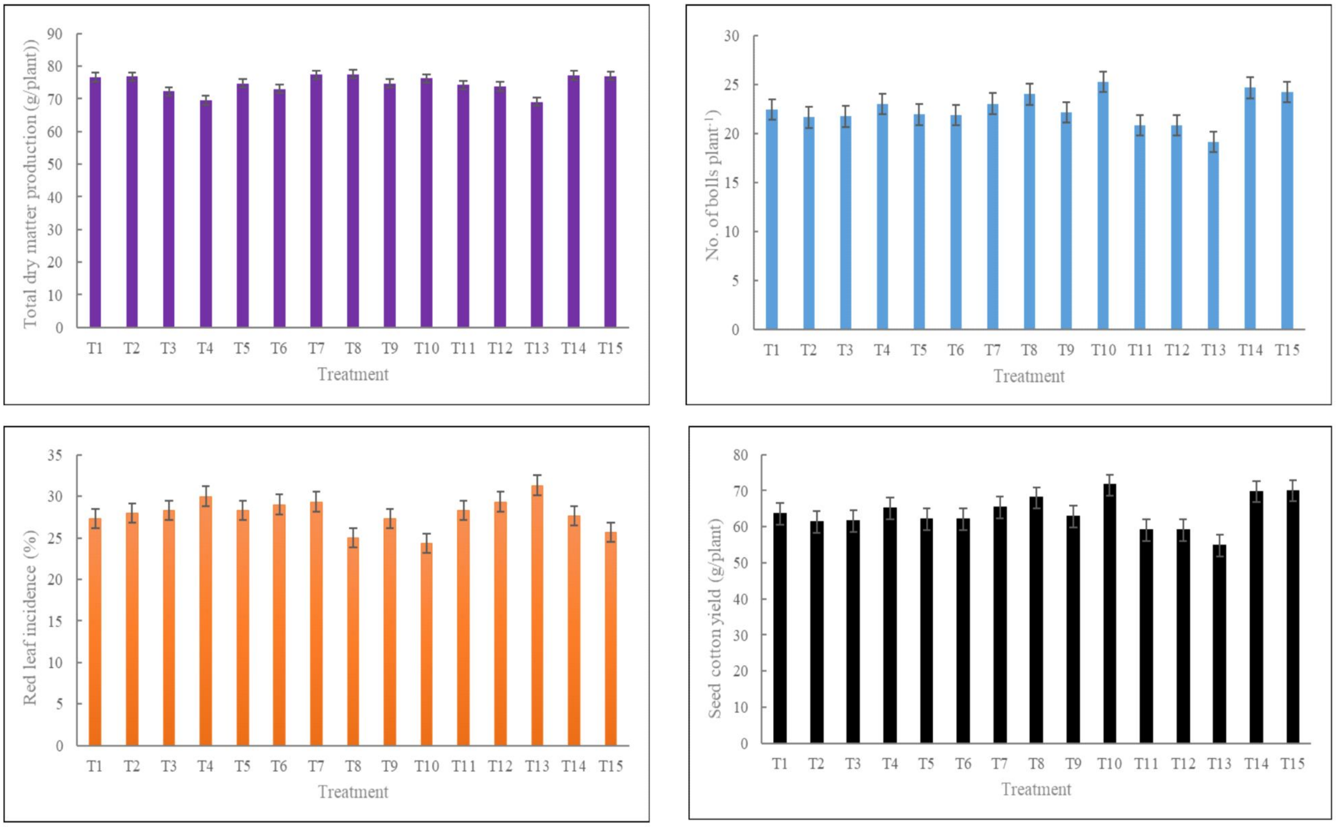

Fig. 1(b) : Effects of Foliar sprays and Irrigation strategies on growth, physiological traits and yield of Bt cotton (*Gossypium hirsutum* L.). **Note:** T_1- NPK spray (10:5:5 kg ha^{-1}), T_2- Ascorbic acid spray @500 ppm, T_3- PMA spray @10 ppm, T_4- CCC spray @ 500 ppm, T_5- Kinetin spray @10 ppm, T_6- AA+PMA spray @500 ppm (1:1), T_7- $MgSO_4$ spray @0.5%, T_8- $MgSO_4$ spray @ 1%, T_9- Micro nutrients (Hoagland solution) spray @1 ml L^{-1}, T_{10}- DAP spray @2%, T_{11}- GA_3 spray 50 ppm, T_{12}- KNO_3 spray @ 1%, T_{13}- Control (No spray), T_{14}- Irrigation at critical stages (flowering and boll development), T_{15}- Urea spray @ 2%.

T_{14} and T_{15}.

Leaf reddening in cotton is mainly because of accumulation of Anthocyanin pigment in leaf. Maximum red leaf incidence was found in treatment T_{13} (Control). This might be due to the deficiency of magnesium and nitrogen. At 120 DAS (boll bursting stage) nitrogen percentage was reduced in reddening affected leaves of Bt cotton. Decrease in leaf nitrogen content caused the leaf reddening. Gradually the chlorophyll moiety of cell is broken down and cells become disorganized with the formation of Anthocyanin pigment giving red appearance to leaf.

Treatment T_8 (MgSO4 spray @ 1%), T_{10} (DAP spray 2%) showed lower red leaf incidence. This might be due to the foliar spray of $MgSO_4$, DAP and Urea which are known to possess linkage in the formation and development of chlorophyll, which is used as prophylactic measures, which help to reduce the incidence of leaf reddening disorder. similar results were also reported in previous studies (Khader and Prakash, 2007).

Yield and yield contributing traits

Number of bolls plant^{-1}

The data on the number of cotton bolls plant-1 was determined to be statistically significant at 120 DAS, as indicated in Table 1 and Fig. 1(b). Treatments T_{10}, T_{14}, T_{15}, T_8, T_7 and T_4 have all recorded significantly more bolls per plant^{-1} than the control; in contrast, treatment T_{10} (DAP spray @ 2%) has recorded significantly more bolls per plant^{-1} (25.25) than the control, while treatment T_{13} (Control) has recorded the fewest bolls plant^{-1} (19.11) in comparison to other treatments. It was discovered that treatments T_1, T_4, T_7, T_8, T_{14} and T_{15} were comparable to treatment T_{10}. The remaining treatments, however, were determined to be at par control.

Foliar application of $MgSO_4$, urea and DAP significantly increased number of bolls plant^{-1}. This might be due to the beneficial role of Mg in enhancing the enzyme in synthesis of nucleic acids and accumulation of photosynthates which might have increased boll production. Similar results were reported by Kumar and Yadav (2010) as well as Brar and Singh (2022).

Seed cotton yield plant^{-1} (g)

Table 1 and Fig. 1(b) illustrate the statistical significance of the data pertaining to the yield of seed cotton plant^{-1} (g). The results indicate that treatment T_{10} (DAP @ 2%) produced the highest seed cotton yield (71.50 g plant^{-1}) compared to control, whereas treatment T_{13} (control without spray) produced the lowest yield (54.79 g plant^{-1}) overall. There was no difference between treatments T_{10} and T_1, T_4, T_7, T_8, T_{14} and T_{15}.

Foliar application of the magnesium sulphate, urea, DAP and cycocel recorded maximum seed cotton yield. The highest seed cotton yield was recorded with the foliar application of $MgSO_4$. This might be associated with the beneficial role of magnesium in enhancing the enzymatic and photosynthetic activities and accumulation of the photosynthates, which might have reflected in the boll production and development in cotton (Rajkumar and Gurumurty, 2008). The increase in cotton yield attributing characters might be due to nitrogen and phosphorous added to the crop directly available for the development of plant and finally to the seed cotton yield (Nehra and Kumawat, 2003) as well as Brar and Singh (2022).

Conclusion

In this study, significant findings emerged regarding the efficacy of different treatments. $MgSO_4$ spray at 1% demonstrated superior performance in promoting plant height, leaf area and CCI Moreover, treatments involving DAP, urea and Cycocel also showed promising results in improving yield-contributing traits *i.e.*, number of bolls plant^{-1} and seed cotton yield compared with other treatments. So, the application of nutrients and growth regulators facilitated nutrient utilization, leading to increased growth parameter, decreased leaf reddening and yield potential in Bt cotton.

Author contributions

Rajendra R. Lipane: Collect reviews, Data analysis, Interpretation of results, Writing, editing and reviewed manuscript. Amol P. Solanke: Collect reviews, Data analysis, Interpretation of results, Draft manuscript preparation, study conception and design. Arti M. Ambhore: Writing, editing and reviewed manuscript. Bhushan J. Gawhale: Collect reviews, Writing, editing and reviewed manuscript. Avinash G. Borade: Conducted research trial, Observations, Data collection, Data analysis, Interpretation of results. D. V. Durge: Critically reviewed the manuscript and served as scientific advisor. All authors reviewed the results and approved the final version of the manuscript

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