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Influence of post emergent herbicides on growth, yield and fibre quality of *Bt* Cotton in north eastern dry zone of Karnataka

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Abstract
A field experiment was conducted during *kharif* 2025 at Main Agricultural Research Station (MARS), University of Agricultural Sciences, Raichur, Karnataka, to evaluate the effect of post-emergent herbicides application on growth, yield and fibre quality of *Bt* cotton (hybrid SWCH 4749 BG II). The experiment was laid out in a Randomized Complete Block Design (RCBD) with ten treatments and three replications. The treatments comprised four doses of pyrithiobac sodium 10 % + clethodim 10.25 % SE (160, 202.50, 243 and 283 g *a.i.* ha^{-1}), clethodim 25 % EC, pyrithiobac sodium 10 % EC and pyrithiobac sodium 6 % + quizalofop ethyl 4 % MEC, each applied at 3-4 leaf stage of weeds followed by intercultivation at 45 DAS, along with weed-free check, a weedy check and farmer's practice. The weed-free check recorded significantly higher growth parameters, yield attributes and seed cotton yield (2975 kg ha^{-1}) and was on par with farmer's practice (2750 kg ha^{-1}). Among the herbicidal treatments, pyrithiobac sodium 10 % + clethodim 10.25 % SE @ 283 g *a.i.* ha^{-1} recorded significantly higher plant height (152.4 cm), sympodial branches (26.0 $plant^{-1}$), leaf area (118.79 dm^2 $plant^{-1}$), total dry matter production (398.68 g $plant^{-1}$), bolls (25.2 $plant^{-1}$), boll weight (5.76 g) and seed cotton yield (2680 kg ha^{-1}). These values were statistically on par with pyrithiobac sodium 10 % + clethodim 10.25 % SE @ 243 g *a.i.* ha^{-1} (2630 kg ha^{-1}) and pyrithiobac sodium 6 % + quizalofop ethyl 4 % MEC (2532 kg ha^{-1}). The weedy check recorded the lower values for all these parameters, including a seed cotton yield (1263 kg ha^{-1}). The quality parameters *viz*., fibre length, fineness and bundle strength were not significantly influenced by the herbicide treatments.

Keywords: *Bt* cotton, clethodim, pyrithiobac sodium, post-emergent herbicide, weed control efficiency, weed index, seed cotton yield

Introduction
Cotton (*Gossypium hirsutum* L.) is one of the major commercial fibre crops of the world and is widely cultivated under tropical and subtropical conditions. Popularly known as "white gold", it is an important source of natural fibre for the textile industry and provides raw material for ginning, spinning, weaving, processing and marketing, besides supporting employment and livelihoods. India is a major cotton-growing country and is the only country cultivating all four recognized cultivated species. During 2025-26, cotton occupied 114.82 lakh hectares with a production of 290.91 lakh bales and productivity of 431 kg ha^{-1}. In Karnataka, it was grown on 6.80 lakh hectares with a production of 2.27 million bales and productivity of 570 kg ha^{-1} during 2024-25 (Anon. 2025 [1], Anon. 2026a [2] and Anon. 2026b [3]).

Cotton productivity is affected by several biotic and abiotic factors, among which weed infestation is a major constraint. The slow initial growth and wider row spacing of cotton favour weed emergence and establishment, resulting in competition for nutrients, moisture, light and space. The intensity of crop–weed competition depends on weed density, species composition, time of emergence and duration of interference (Prabhu *et al*., 2012 [16], Papamichail *et al*., 2002 [14], Knezevic *et al*., 2002 [8] and Iqbal *et al*., 2019 [6]). Early-season weed competition can substantially reduce crop growth and seed cotton yield, while late-season weeds may interfere with harvesting and affect produce quality.

The weed flora of cotton comprised grasses, sedges and broad-leaved weeds. Common grasses included *Cynodon dactylon*, *Dinebra retroflexa*, *Echinochloa colona* and *Echinochloa crus-galli*, while *Cyperus rotundus* was an important sedge. Broad-leaved weeds included *Abutilon indicum*, *Commelina benghalensis*, *Digera arvensis*, *Mimosa pudica*, *Parthenium hysterophorus*, *Phyllanthus fraternus*, *Tribulus terrestris* and *Xanthium strumarium*. Their occurrence and dominance vary with soil, rainfall, cropping system and management practices (Prabhu *et al*., 2012 [16], Kamble *et al*., 2017 [7] and Veeraputhiran, 2023 [21]), making management of diverse weed flora difficult through a single method or herbicide.

Cotton weeds are traditionally managed through preventive, cultural, mechanical and manual methods. Although hand weeding and intercultivation are effective, they are labour-intensive, costly and often difficult to perform timely under labour scarcity and rainy conditions. Mechanical operations at later crop stages may also be restricted due to crop growth and the risk of crop damage. Hence, chemical weed management, particularly post-emergence herbicides, has gained importance for timely suppression of emerged weeds and reduction of crop-weed competition (Nadanassababady *et al*., 2000 [11], Iqbal *et al*., 2019 [6] and Panchal *et al*., 2024 [12]).

Pyrithiobac sodium is a selective post-emergence herbicide belonging to the pyrimidinyl benzoate group and is primarily effective against susceptible broad-leaved weeds in cotton. It inhibits acetolactate synthase (ALS), thereby interfering with the biosynthesis of branched-chain amino acids and suppressing weed growth. Clethodim is a selective post-emergence graminicide belonging to the cyclohexanedione (DIM) group and inhibits acetyl-CoA carboxylase (ACCase), thereby interfering with fatty-acid biosynthesis and controlling susceptible grassy weeds (Prabhu *et al*., 2012; Rao, 2011; Kumar *et al*., 2023). Thus, their complementary activities against broad-leaved and grassy weeds provide scope for broad spectrum weed management in cotton. However, the efficacy of herbicide combinations depends on weed species, density, growth stage, herbicide dose, crop stage and environmental conditions, necessitating field evaluation under specific agro-ecological conditions. Therefore, the present study was undertaken to evaluate the effect of post-emergent herbicides on growth, yield and fibre quality of *Bt* cotton.

Material and Methods

Experimental site, climate and soil

The experiment was conducted during *kharif* season of 2025 at Main Agricultural Research Station (MARS), University of Agricultural Sciences (UAS), Raichur, which is situated at a latitude of 16° 12′ N, longitude of 77° 20′ E and at an elevation of 407 metres above the mean sea level and falls under the North-Eastern Dry Zone of Karnataka (Zone-2). Total rainfall during 2025 was 752.2 mm (normal 727.7 mm) of which 595.2 mm received during the crop period (July to December). Mean monthly maximum and minimum temperatures during this period ranged from 29.1 to 32.6 °C and from 13.1 to 22.4 °C, respectively. The soil of the experimental site was deep black soil having pH 8.10 with electrical conductivity of 0.35 dS m^{-1}, 0.70 per cent organic carbon, 225 kg ha^{-1} available nitrogen, 23 kg ha^{-1} available phosphorus (P_2O_5) and 410 kg ha^{-1} available potassium (K_2O).

Experimental design and treatment details

The experiment was laid out in Randomized Complete Block Design (RCBD) with three replications and ten treatments comprising different treatments *viz*., pyrithiobac sodium 10 % + clethodim 10.25 % SE @ 160 g *a.i.* ha^{-1} at 3-4 leaf stage (PoE) *fb* IC at 45 DAS (T_1), pyrithiobac sodium 10 % + clethodim 10.25 % SE @ 202.50 g *a.i.* ha^{-1} at 3-4 leaf stage (PoE) *fb* IC at 45 DAS (T_2), pyrithiobac sodium 10 % + clethodim 10.25 % SE @ 243 g *a.i.* ha^{-1} at 3-4 leaf stage (PoE) *fb* IC at 45 DAS (T_3), pyrithiobac sodium 10 % + clethodim 10.25 % SE @ 283 g *a.i.* ha^{-1} at 3-4 leaf stage (PoE) *fb* IC at 45 DAS (T_4), clethodim 25 % EC @ 180 g *a.i.* ha^{-1} at 3-4 leaf stage (PoE) *fb* IC at 45 DAS (T_5), pyrithiobac sodium 10 % EC @ 75 g *a.i.* ha^{-1} at 3-4 leaf stage (PoE) *fb* IC at 45 DAS (T_6), pyrithiobac sodium 6 % + quizalofop ethyl 4 % MEC @ 112.5 g *a.i.* ha^{-1} at 3-4 leaf stage (PoE) *fb* IC at 45 DAS (T_7), weed-free check with hand weeding at 20, 40 and 60 DAS + IC at 25, 45 and 65 DAS (T_8), weedy check (T_9) and farmer's practice with hand weeding at 25 and 55 DAS + IC at 30 and 60 DAS (T_{10}).

Crop details and herbicide application

The *Bt* cotton hybrid SWCH 4749 BG II (US 7067) was used for sowing the experiment. This is a high-yielding *Bt* cotton hybrid possessing *Cry1Ac* and *Cry2Ab* genes for resistance against bollworms. The crop was sown on 3rd July 2025 at a spacing of 90 cm × 60 cm. The post-emergent herbicides were applied at the 3-4 leaf stage of the weeds or 20-25 days after sowing using a hand-operated knapsack sprayer fitted with a suitable nozzle at a spray volume of 500 L ha^{-1}. The herbicides spray and intercultivation operations were done as per the treatment details. The recommended dose of fertilizers (RDF) comprising 180 kg N, 90 kg P_2O_5 and 90 kg K_2O ha^{-1} was applied as per the recommended package of practices.

Data collection and observations

Growth parameters (plant height, number of monopodial and sympodial branches, leaf area and total dry matter production), yield attributes (total number of bolls per plant and boll weight), seed cotton yield and fibre quality parameters (fibre length, bundle strength and fibre fineness) were recorded at harvest. All observations were recorded from the net plot area, following standard procedures.

Statistical analysis

The data were statistically analysed using Fisher's method of analysis of variance and the significance of treatment effects was tested at the 5 per cent probability level (P = 0.05), as described by Bartlett (1947) [4].

Results and discussion

Growth parameters

The growth parameters of *Bt* cotton, including plant height, number of monopodial and sympodial branches, leaf area and total dry matter production, differed significantly among weed-management practices at harvest and the results are presented in Table 2.

At harvest, among all the treatments, the weed-free check (T_8) recorded significantly higher plant height (172.9 cm), number of monopodial branches (2.97 $plant^{-1}$), sympodial branches (29.9 $plant^{-1}$), leaf area (139.92 dm^2 $plant^{-1}$) and total dry matter production (458.25 g $plant^{-1}$) and was

statistically on par with farmer's practice (T_{10}), which recorded 170.70 cm, 2.86 plant^{-1}, 29.3 plant^{-1}, 134.56 dm^2 plant^{-1} and 451.45 g plant^{-1}, respectively. Among the herbicidal treatments, application of pyrithiobac sodium 10 % + clethodim 10.25 % SE @ 283 g *a.i.* ha^{-1} at the 3-4 leaf stage of weeds as PoE *fb* IC at 45 DAS (T_4) recorded significantly higher plant height (153.0 cm), number of monopodial branches (2.55 plant^{-1}), sympodial branches (26.0 plant^{-1}), leaf area (118.79 dm^2 plant^{-1}) and total dry matter production (398.68 g plant^{-1}) and were statistically on par with application of the same herbicide combination @ 243 g *a.i.* ha^{-1} (T_3), which recorded 151.70 cm, 2.52 plant^{-1}, 24.8 plant^{-1}, 117.35 dm^2 plant^{-1} and 390.85 g plant^{-1}, respectively and pyrithiobac sodium 6 % + quizalofop ethyl 4% MEC @ 112.5 g *a.i.* ha^{-1} (T_7), which recorded 149.60 cm, 2.49 plant^{-1}, 24.2 plant^{-1}, 115.59 dm^2 plant^{-1} and 392.34 g plant^{-1}, respectively. In contrast, continuous weed infestation resulted in significantly lower plant height (104.3 cm), number of monopodial branches (0.97 plant^{-1}), sympodial branches (13.5 plant^{-1}), leaf area (78.64 dm^2 plant^{-1}) and total dry matter production (278.47 g plant^{-1}) in the weedy check (T_9).

The superior growth under the weed-free check and farmer's practice could be attributed to effective weed suppression, which reduced competition for moisture, nutrients, light and space. The herbicidal treatments also maintained better plant growth than the untreated control by suppressing weeds during different growth stages. Pyrithiobac sodium inhibits acetolactate synthase (ALS), disrupting the synthesis of essential branched-chain amino acids and proteins in broadleaf weeds, while clethodim inhibits acetyl-CoA carboxylase (ACCase), interfering with fatty acid synthesis and effectively controlling grassy weeds. The complementary action of these herbicides improved resource availability, leaf development, photosynthetic activity and assimilate production, thereby promoting stem elongation, branching and dry matter accumulation. In contrast, continuous weed interference in the untreated control intensified competition for essential resources, restricted nutrient and water uptake, reduced leaf development and photosynthetic activity, and consequently limited crop growth and biomass production. Similar improvements in cotton growth under effective weed-management practices were reported by Singh and Kokate (2010) [20], Hargilas *et al.* (2015) [5] and Pawar *et al.* (2015) [15].

Yield attributes and yield

The total number of bolls per plant and boll weight differed significantly among the weed-management treatments and the results are presented in Table 2. Among the herbicidal treatments, application of pyrithiobac sodium 10% + clethodim 10.25% SE @ 283 g *a.i.* ha^{-1} at the 3-4 leaf stage of weeds as PoE *fb* IC at 45 DAS (T_4) recorded significantly more bolls (25.2 plant^{-1}) and higher boll weight (5.76 g) and seed cotton yield (2680 kg ha^{-1}). These values were statistically on par with application of the same herbicide combination @ 243 g *a.i.* ha^{-1} (T_3), which recorded 24.9 bolls plant^{-1}, 5.72 g and 2630 kg ha^{-1} respectively, and application of pyrithiobac sodium 6% + quizalofop ethyl 4% MEC @ 112.5 g *a.i.* ha^{-1} at the 3–4-leaf stage of weeds as PoE *fb* IC at 45 DAS (T_7) that recorded 23.7 bolls plant^{-1}, 5.69 g and seed cotton yield (2532 kg ha^{-1}) respectively. The remaining herbicidal treatments recorded significantly lower values for these attributes. Among all the treatments, the weed-free check (T_8) recorded significantly more bolls (28.0 plant^{-1}) and higher boll weight (5.93 g) and seed cotton yield (2975 kg ha^{-1}) which were statistically on par with farmer's practice (T_{10}) that recorded 26.5 bolls plant^{-1} and 5.81 g, 2750 kg ha^{-1} respectively. In contrast, the weedy check (T_9) recorded significantly fewer bolls (14.5 plant^{-1}) and lower boll weight (4.47 g) and seed cotton yield (1263 kg ha^{-1}).

The higher seed cotton yield under the weed-free check, farmer's practice and effective herbicidal treatments could be attributed to reduced crop-weed competition, which improved water and nutrient uptake, canopy development and photosynthetic efficiency. Enhanced assimilate production and translocation towards reproductive sinks promoted dry matter accumulation, sympodial branching, boll retention and boll filling, thereby increasing seed cotton yield. Although the weed-free check recorded an 8.18 % yield advantage over farmer's practice, their statistical similarity indicated that effective weed management through farmer's practice could achieve comparable yields with potentially lower labour requirements. Conversely, prolonged weed interference in the untreated control restricted resource acquisition and canopy photosynthesis, limiting assimilate partitioning to reproductive structures and reducing boll retention and filling. Consequently, seed cotton yield was 54.07 % lower than under farmer's practice. These findings are consistent with Hargilas *et al.* (2015) [5], Singh *et al.* (2016) [19], Panchal *et al.* (2022) [12] and Reddy *et al.* (2023) [18].

Fibre quality

Mean fibre length, fibre fineness and bundle strength did not differ significantly among the weed-management treatments (Table 2). Numerically higher values were recorded under the weed-free check (T_8) (31.6 mm, 3.9 µg inch^{-1} and 30.7 g tex^{-1}, respectively), followed by farmer's practice (T_{10}) (31.1 mm, 3.7 µg inch^{-1} and 30.2 g tex^{-1}, respectively). Among the herbicidal treatments, application of pyrithiobac sodium 10 % + clethodim 10.25% SE @ 283 g *a.i.* ha^{-1} at the 3-4 leaf stage of weeds as PoE *fb* intercultivation at 45 DAS (T_4) recorded 30.8 mm fibre length, 3.6 µg inch^{-1} fibre fineness and 29.9 g tex^{-1} bundle strength. In contrast, the weedy check (T_9) recorded numerically lower values of 30.2 mm, 3.1 µg inch^{-1} and 28.3 g tex^{-1}, respectively. Fibre length across treatments (30.2-31.6 mm) remained within the 30-32 mm range reported for the hybrid. Fibre quality is primarily governed by genetic factors, with environmental stresses, including weed competition, contributing to variation. However, the absence of significant differences among treatments indicated that fibre quality remained largely unaffected by the weed-management practices, despite numerically better values under effective weed control. Similar findings were reported by Muhammad *et al*. (2009) [10].

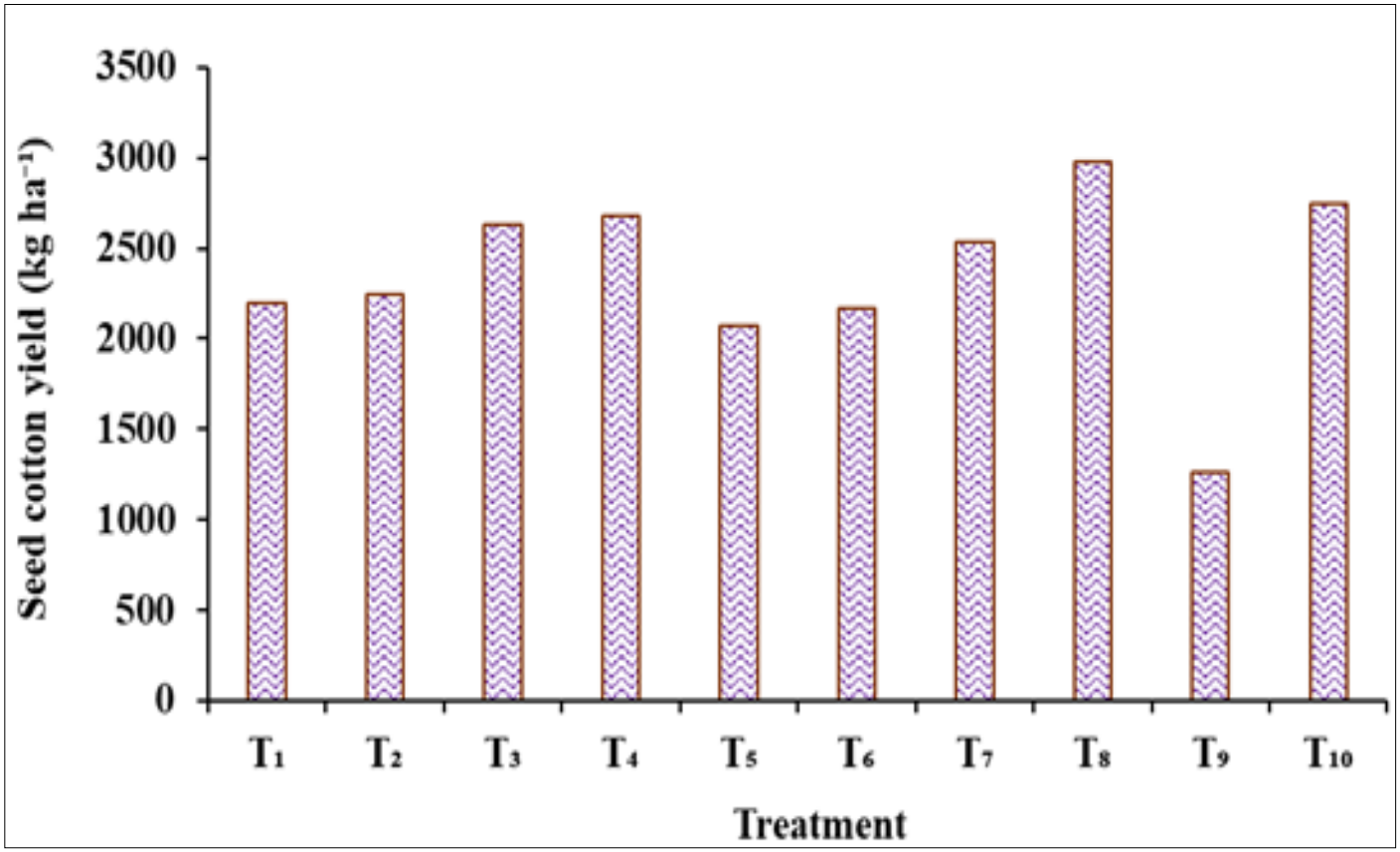


Fig 1: Seed cotton yield of *Bt* cotton as influenced by weed management practices

Table 1: Plant height, No. of branches, leaf area and total dry matter production of *Bt* cotton at harvest as influenced by weed management practices

Treatment	Plant height (cm)	No. of monopodial branches per plant	No. of sympodial branches per plant	Leaf area (dm^2 $plant^{-1}$)	Total dry matter production (g $plant^{-1}$)
T_1: Pyrithiobac sodium 10 % + Clethodim 10.25 % SE @ 160 g *a.i.* ha^{-1} at 3-4 leaf stage (PoE) *fb* IC at 45 DAS	133.2	2.00	19.6	99.51	337.97
T_2: Pyrithiobac sodium 10 % + Clethodim 10.25 % SE @ 202.50 g *a.i.* ha^{-1} at 3-4 leaf stage (PoE) *fb* IC at 45 DAS	134.4	2.04	20.8	102.95	344.65
T_3: Pyrithiobac sodium 10 % + Clethodim 10.25 % SE @ 243 g *a.i.* ha^{-1} at 3-4 leaf stage (PoE) *fb* IC at 45 DAS	149.7	2.52	24.8	117.35	390.85
T_4: Pyrithiobac sodium 10 % + Clethodim 10.25 % SE @ 283 g *a.i.* ha^{-1} at 3-4 leaf stage (PoE) *fb* IC at 45 DAS	152.4	2.55	26.0	118.79	398.68
T_5: Clethodim 25% EC @ 180 g *a.i.* ha^{-1} at 3-4 leaf stage (PoE) *fb* IC at 45 DAS	130.0	1.85	18.5	90.01	321.61

T_6: Pyrithiobac sodium 10 % EC @ 75 g *a.i.* ha^{-1} at 3-4 leaf stage (PoE) *fb* IC at 45 DAS	131.8	1.92	19.0	92.34	328.91
T_7: Pyrithiobac sodium 6 % + Quizalofop ethyl 4 % MEC @ 112.5 g *a.i.* ha^{-1} at 3-4 leaf stage (PoE) *fb* IC at 45 DAS	147.6	2.49	24.2	115.59	392.34
T_8: Weed free check (Hand weedings at 20, 40 and 60 DAS + IC at 25, 45 and 65 DAS)	172.9	2.97	29.9	139.92	458.25
T_9: Weedy check	102.3	0.97	13.5	78.64	278.47
T_{10}: Farmer's practice (Hand weedings at 25 and 55 DAS + IC at 30 and 60 DAS)	170.7	2.86	29.3	134.56	451.45
S. Em.±	5.8	0.10	1.1	5.07	16.70
C. D. at 5 %	17.2	0.29	3.1	15.06	49.63

Note- EC: Emulsifiable concentrate SE: Suspo-emulsion IC: Intercultivation DAA: Days after application
MEC: Microemulsion concentrate POE: Post emergence DAS: Days after sowing a.i.: active ingredient

Table 2: Yield attributes and fibre quality of *Bt* cotton as influenced by weed management practices

Treatment	Total number of bolls per plant	Boll weight (g)	Seed cotton yield (kg ha^{-1})	fibre length (mm)	Fibre fineness (µg inch^{-1})	Bundle strength (g tex^{-1})
T_1: Pyrithiobac sodium 10 % + Clethodim 10.25 % SE @ 160 g *a.i.* ha^{-1} at 3-4 leaf stage (PoE) *fb* IC at 45 DAS	20.8	5.58	2197	30.6	3.4	29.0
T_2: Pyrithiobac sodium 10 % + Clethodim 10.25 % SE @ 202.50 g *a.i.* ha^{-1} at 3-4 leaf stage (PoE) *fb* IC at 45 DAS	21.3	5.60	2245	30.6	3.5	29.3
T_3: Pyrithiobac sodium 10 % + Clethodim 10.25 % SE @ 243 g *a.i.* ha^{-1} at 3-4 leaf stage (PoE) *fb* IC at 45 DAS	24.9	5.72	2630	30.7	3.6	29.7
T_4: Pyrithiobac sodium 10 % + Clethodim 10.25 % SE @ 283 g *a.i.* ha^{-1} at 3-4 leaf stage (PoE) *fb* IC at 45 DAS	25.2	5.76	2680	30.8	3.6	29.9
T_5: Clethodim 25% EC @ 180 g *a.i.* ha^{-1} at 3-4 leaf stage (PoE) *fb* IC at 45 DAS	19.5	5.47	2067	30.4	3.2	28.6
T_6: Pyrithiobac sodium 10 % EC @ 75 g *a.i.* ha^{-1} at 3-4 leaf stage (PoE) *fb* IC at 45 DAS	20.1	5.54	2170	30.5	3.3	28.9
T_7: Pyrithiobac sodium 6 % + Quizalofop ethyl 4 % MEC @ 112.5 g *a.i.* ha^{-1} at 3-4 leaf stage (PoE) *fb* IC at 45 DAS	23.7	5.69	2532	30.6	3.5	29.4
T_8: Weed free check (Hand weedings at 20, 40 and 60 DAS + IC at 25, 45 and 65 DAS)	28.0	5.93	2975	31.6	3.9	30.7
T_9: Weedy check	14.5	4.47	1263	30.2	3.1	28.3
T_{10}: Farmer's practice (Hand weedings at 25 and 55 DAS + IC at 30 and 60 DAS)	26.5	5.81	2750	31.1	3.7	30.2
S. Em.±	0.6	0.05	95	1.7	0.2	1.8
C. D. at 5 %	1.9	0.15	281	NS	NS	NS

Note- EC: Emulsifiable concentrate SE: Suspo-emulsion IC: Intercultivation DAA: Days after application
MEC: Microemulsion concentrate POE: Post emergence DAS: Days after sowing a.i.: active ingredient

Conclusion

Application of pyrithiobac sodium 10 % + clethodim 10.25 % SE at 283 g *a.i.* ha^{-1} as a post-emergence treatment at the 3-4 leaf stage followed by intercultivation at 45 days after sowing, effectively improved the growth attributes, yield attributes and seed cotton yield (2680 kg ha^{-1}) of *Bt* cotton over the weedy check (1263 kg ha^{-1}) among the herbicidal treatments, without significantly affecting fibre quality. This treatment was statistically at par with application of the same herbicide combination at 243 g *a.i.* ha^{-1} and with pyrithiobac sodium 6 % + quizalofop ethyl 4 % MEC in terms of growth, yield attributes and seed cotton yield. Therefore, application of pyrithiobac sodium 10 % + clethodim 10.25 % SE at 243 g *a.i.* ha^{-1}, followed by intercultivation at 45 days after sowing, proved to be an effective weed-management practice for improving growth and seed cotton productivity in *Bt* cotton.

References

1. Anonymous. Agricultural Statistics at a Glance 2024-25. New Delhi: Directorate of Economics and Statistics, Department of Agriculture and Farmers Welfare, Ministry of Agriculture and Farmers Welfare, Government of India, 2025.
2. Anonymous. India's Cotton Sector and Mission for Cotton Productivity. New Delhi: Press Information Bureau, Government of India, 2026a.
3. Anonymous. Cotton production, area and productivity: 2025-26. New Delhi: Press Information Bureau, Government of India, 2026b.
4. Bartlett MS. The use of transformation. Biometric Bull.,1947:3:9-52.
5. Hargilas, Ameta GS, Jat SC, Saini DP. Evaluation of effective weed management strategy for *Bt* cotton. Int. Quarterly J. Life Sci.,2015:10(3):1313-1316.
6. Iqbal N, Khan AM, Chauhan BS. Weed management in cotton. In: Jabran, K. and Chauhan, B.S. (eds.) Cotton Production. Hoboken, NJ: Wiley, 2019, 109-126.
7. Kamble AB, Danawale NJ, Rajendrakumar. Integrated weed management in *Bt* cotton. Indian J. Weed Sci.,2017:49(4):405-408.
8. Knezevic SZ, Evans SP, Blankenship EE, Van Acker RC, Lindquist JL. Critical period for weed control: The concept and data analysis. Weed Sci.,2002:50:773-786.
9. Kumar P, Meena H, Singh P. Evaluation of post emergence herbicides for controlling grassy weeds in cotton. Chem. Sci. Rev. Lett.,2023:12(46):116-120.
10. Muhammad D, Muhammad N, Ilyas A, Muhammad R, Mian A. Effect of mechanical and chemical weed control on the productivity of cotton. Pak. J. Weed Sci. Res.,2009:15(2):117-122.
11. Nadanassababady T, Kandasamy OS, Ramesh G. Integration of pre and non-selective post-emergence herbicides and cultural method for weed control in cotton and its effect on succeeding crops. Trop. Agric. Res.,2000:12:217-225.
12. Panchal PS, Patel VJ, Chaudhari DD, Dohat MP. Evaluation of different herbicides on growth, yield attributes and yield of *Bt* cotton and their residual effect on succeeding summer groundnut. Pharma Innov. J.,2022:11(12):2421-2424.
13. Panchal PS, Patel VJ, Patel BD, Chaudhari DD. Weed management in *Bt* cotton through sequential and tank mix application of different herbicides. Indian J. Weed Sci.,2024:56(1):59-62.
14. Papamichail D, Eleftherohorines I, Gravanis. Critical periods of weeds competition in cotton in Greece. Phytoparasitica.,2002:30(1):105-111.
15. Pawar PM, Thakare SS, Deshmukh JP, Shingrup PV, Chirde PN. Efficacy of pre and post emergence herbicides in *Bt* cotton (*Gossyium hisutum* L.) under rainfed condition. Plant Arch.,2015:15(1):475-478.
16. Prabhu G, Halepyati AS, Pujari BT, Desai BK. Weed management in *Bt* cotton (*Gossypium hirsutum* L.) under irrigation. Karnataka J. Agric. Sci.,2012:25(2):183-186.
17. Rao AS. Evaluation of pyrithiobac alone and in combination with grassy herbicides on weed control in cotton. WCRC-5: Technol. Prosperity. Mumbai,2011:7(11):406-409.
18. Reddy V, Kulkarni S, Chavan M, Ajayakumar MY. Effects of integrated weed management practices on weed parameters and yield of *Bt* cotton (*Gossypium hirsutum* L.). Int. J. Environ. Clim. Change,2023:13(11):324-331.
19. Singh K, Singh HP, Singh K. Weed management in cotton with pre and post emergent herbicides. Indian J. Weed Sci.,2016:48(3):348-350.
20. Singh M, Kokate KD. Weed management and its effect on cotton (*Gossypium hirsutum* L.). Ann. Plant Prot. Sci.,2010:18(2):484-487.
21. Veeraputhiran R. Integrated weed management in irrigated cotton under high density planting system. Indian J. Weed Sci.,2023:55(1):42-45.