Priyanka *et al. Journal of Cotton Research (2024) 7:35*
https://doi.org/10.1186/s42397-024-00199-6

Journal of Cotton Research

RESEARCH Open Access

Performance of Bt cotton evaluated in relation to mulching and weed control measures in northwest India

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Abstract

Background Weed infestation in cotton has been reported to offer severe competition and cause yield reduction to a large extent. Weeding via cultural practices is time consuming, tedious, and expensive due to long duration of cotton crop and regular monsoon rains during cotton production in India. Chemical weed control has been successfully utilized in cotton in the recent past. However, continuous use of similar herbicides leads to resistance in weeds against herbicides. And when sprayed to the field, herbicides not only suppress weeds but leave undesirable residues in the soil that are hazardous to the environment. Therefore, a study was performed at cotton research area at Chaudhary Charan Singh Haryana Agricultural University, Hisar, Haryana during two consecutive *kharif* seasons (2020 and 2021) to determine the most suitable and sustainable weed management strategy through the integration of chemical and cultural methods.

Results Mulching with rice straw of 7.5 t ha^{-1} resulted in significantly higher cotton seed yield (3 189 and 3 084 kg ha^{-1}) and better weed control in comparison to no mulch treatments (2 990 and 2904 kg ha^{-1}) in 2020 and 2021, respectively. Among various weed management levels, the significantly lowest cotton seed yield was recorded in untreated control (1 841 and 1 757 kg·ha^{-1} during 2020 and 2021, respectively) in comparison to other treatments while all other treatments were statistically at par with each other during both years of crop experimentation.

Conclusion Mulching with rice straw of 7.5 t·ha^{-1} along with a pre-emergence application of pendimethalin (active ingredient) at 1.5 kg·ha^{-1} *fb* (followed by) one hoeings at 45 days after sowing (DAS) and *fb* glyphosate 2 kg·ha^{-1} (Shielded spray) at 90 DAS is a viable option for effective control of grassy and broadleaved weeds in Bt cotton in north-west India.

Keywords Bt Cotton, Pre- and post-emergence herbicides, Rice straw mulching, Weed management

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Background

Cotton is planted around 12 million hectares of land in India, which ranks the first in output with 34 million bales among all cotton producing countries in the world. In comparison, the global planting area is 31.6 million hectares, with 113.1 million bales produced. India's average cotton productivity is 469 kg·ha^{-1}, which is low when compared with the global average of 778 kg·ha^{-1} [Cotton Association of India (CAI), 2022]. Cotton is grown extensively in Karnataka, Madhya Pradesh, Maharashtra, Gujarat, Punjab, Uttar Pradesh, Rajasthan, Haryana, and Tamilnadu. The state of Maharashtra produces the most cotton in India, followed by Gujarat and Andhra Pradesh. The area of cotton crop in Haryana was 6.48×10^5 ha, with the production of 1.89 million bales (1 bale is equal to 170 kg of cotton weight) and a lint yield of 497 kg·ha^{-1} according to CAI (2022). It is a major cash crop in Haryana during the *kharif* season, and it contributes significantly to the state's economy in terms of employment and export revenues. Sirsa, Hisar, Jind, and Fatehabad are the four largest cotton-growing districts in Haryana, known as the cotton belt.

Cotton yields fluctuate from year to year due to insect pests and diseases that are directly linked to the region's climatic conditions. Because the cotton has a long development cycle, it is subjected to numerous rains and facing the major issue of weed. Yield losses in cotton due to weeds range from 50% to 85%, depending on the type and severity of the weeds. In cotton, the critical period for weed competition was 15 to 60 days after sowing (DAS) (Sharma, 2008). Cotton fields are infested with a diverse range of weeds that are more adaptable to extreme conditions under climatic, edaphic, and biotic stressors. Weed's great persistence is due to their ability to produce a large number of seeds with excellent viability.

Carpet weed (*Trianthema portulacastrum* L.), jungle rice (*Echinochloa colona* L.), and purple nut sedge (*Cyperus rotundus* L.) are three significant weeds that infest in cotton field in north-west India, causing production up to 70% losses depending on the type and density of weeds (Balyan et al., 1983; Brar et al., 1992). During the first 60 days of crop growth, cotton is extremely susceptible to weed competition. Weed interference, cotton damage, and the critical phase of cotton-weed competition last 30 to 60 days, accounting for almost half of the cotton growing season (Ayyadurai et al., 2013). Cotton is sown in wide row spacing and it grows slowly in the summer due to high temperature ranging from 41 to 47 °C (Prasad et al., 1997), giving weeds plenty of space to grow, especially in the first two months after sowing. In the current agricultural production system, manual weed management without herbicide application is the most labor-intensive, expensive, and unfeasible (due to labour shortages) option. Herbicides have remained the primary tool and the most effective weed control programmes in such circumstances (Zhang, 2003; Norsworthy et al., 2012).

Weeds can be effectively managed when ecological strategies like mulching are combined with chemical methods. Mulching is covering the soil surface with a layer of mulch to improve plant growth and development. Mulch is used for a variety of reasons, one of which is to control weeds (Lamont, 2005). Mulch serves as a physical barrier against weeds. In the absence of inter-row cultivation and with regular monsoon rains, weeds germinate in different spells and compete with cotton plants and cause reduction in the seed cotton yield. It is necessary to apply pre-emergence (PRE) herbicides followed by post-emergence herbicides to reduce weed competition at the critical period (Pawar, et al., 2000). Pre-application of pendimethalin in combination with inter-row cultivation and hand-weeding may be used as efficient weed control methods to get higher yields of flat-sown cotton (Ali et al., 2013).

Despite the availability of several Pre-herbicides for weed control, the post-emergence herbicide is commonly considered to control weeds that arise during the later phases of crop growth. Furthermore, because labour availability for cotton cultivation is becoming increasingly scarce, the use of post emergence herbicides has a greater potential for effective management of weeds (Veeraputhiran et al., 2015).

Up to 90% of cotton crop's output can be lost due to poor weed control. Without doubt, the sustainable weed management would be ensured by the inclusion of non-chemical approaches and diversifying weed control options (Manalil et al., 2016). It is necessary to develop new techniques to combat with weeds since the practice to suppress weeds year after year has been proven to lead to the directed evolution toward weed resistance. The present study was to investigate efficacy of mulching, Pre- and post-emergence herbicide on the performance of cotton and weed dynamics.

Materials and methods

Site description

The experiment was carried out at cotton research area of Chaudhary Charan Singh Haryana Agricultural University (CCS HAU), Hisar during *kharif* season 2020 and 2021. It is situated in the sub-tropics at longitude 75°46'E, latitude 29°10'N and altitude of 215.2 m above mean sea level in Haryana. The experimental field that cotton was grown in *kharif* season was the fallow land in the last three years. *Digeria arvensis, T. portulacastrum, C. rotundus, E. colona*, etc., were the major weeds infested in the experimental field during previous season. Experimental soil was loamy sand with 72.8% sand, 15.9% silt, and 11.3% clay with a pH of 7.8, 0.45% organic carbon, 161 kg·ha^{-1} available nitrogen, 17 kg·ha^{-1} available phosphorus, and 279 kg·ha^{-1} available potassium.

Field preparation and sowing

At proper moisture condition, the field was prepared by a primary harrowing tillage operation with a tractor drawn disc harrow followed by the cultivator and planking after the pre-sowing irrigation. Sowing was done by dibbling method on well-prepared bed with row-to-row spacing of 100 cm and plant-to-plant spacing of 45 cm. Thinning was done to keep one plant per hill. Recommended dose of fertilizer, i.e., N, P_2O_5, and K_2O for Bt cotton was 175, 60, and 60 kg·ha^{-1} applied in the field. One-third of nitrogen, full amount of phosphorus and potassium is supplied through urea, diammonium phosphate (DAP) and muriate of potash, respectively, at the time of sowing. The remaining two-third of nitrogen was top dressed in two equal splits, *i.e.*, at the squaring and flowering stage. The first irrigation was applied at 55 DAS and the second irrigation applied 30 d after the first irrigation. RCH 776 genotype of Bt cotton was grown as per the recommended package of practices.

Treatment details

The experiment was laid out in a factorial randomized block design with two factors of different levels, replicated thrice. Each plot size was 8.0×9.0 m. The first factor was different levels of mulching, *i.e.*, No mulching (M_1), Mulching with paddy straw 7.5 t·ha^{-1} (M_2); and the second factor was weed management, *i.e.*, Untreated control (W_1), Weed free (W_2), Pendimethalin (Pre) (active ingredient, same as follows) 1.5 kg·ha^{-1} *fb* (followed by) two hoeings at 45 and 90 DAS (W_3), Two hoeings at 30 and 60 DAS *fb* quizalofop-p-ethyl 62.5 g·ha^{-1} at 90 DAS (W_4), Two hoeings at 30 and 60 DAS *fb* propaquizafop-p-ethyl 50 g·ha^{-1} at 90 DAS (W_5), Pendimethalin (Pre) 1.5 kg·ha^{-1} *fb* one hoeing at 45 DAS *fb* paraquat 1 kg·ha^{-1} (shielded spray) at 90 DAS (W_6), and Pendimethalin (Pre) 1.5 kg·ha^{-1} *fb* one hoeing at 45 DAS *fb* glyphosate 2 kg·ha^{-1} (shielded spray) at 90 DAS (W_7). Pre herbicide was applied just after sowing, *i.e.*, pendimethalin as per treatment with the help of knapsack sprayer fitted with flat fan nozzle using a spray with the volume of 500 L·ha^{-1}. Mulching was done after application of pre-emergence herbicide. As cotton crop grown at wide row spacing, shielded spray of paraquat and glyphosate was achieved by directly spraying on weeds by using protected shield around the nozzle. Weed free condition was maintained by hand weeding when it was required.

Weather parameters

Hisar has a semi-arid climate with very hot summers (temperatures soar to 45 °C sometimes) and very cold winters (temperatures drop to 1–2 °C sometimes). The mean monthly temperature exhibits a broad range of variation in minimum and maximum temperatures throughout the summer and winter seasons. The total rainfall received during the *kharif* cotton growing period was 364.2 mm (2020) and 770.6 mm (2021). Mean weekly maximum and minimum temperatures ranged between 29.7–43.2 °C and 9.8–28.3 °C during *kharif* 2020, respectively, and 28.9–41.4 °C and 11.8–28.1 °C during *kharif* 2021, respectively (Fig. 1).

Biometric observations

Cotton plants in each plot were selected randomly to represente the whole plot and the selected plants were labelled. Total seed cotton harvested from two pickings in each plot was recorded as seed cotton yield in kg·ha^{-1}. Data on different weed parameters were recorded before hoeing. Weed density (plants per m^2) and biomass were recorded at 30 DAS before hoeing and 120 DAS using two quadrats of 50 cm×50 cm in each plot. For biomass, all weeds (which were counted during density recording) were cut at ground level, separated by species, sun dried, and then placed in oven at 70 ℃ for 72 h, weighed and recorded as g·m^{-2}.

Statistical analysis

The experimental data recorded for growth and yield characters were subjected to statistical analysis in accordance with "Analysis of Variance" by Fisher (1950). Data on weed density and weed dry weight have shown high degree of variation. Therefore, the data on weed count and weed dry weight were subjected to square root transformation to make analysis of variance more valid. The means were compared using *LSD* test at 5% probability when the *F*-values were significant (Table S1).

Results

Weed density

The weed density of all weeds including grass weeds, sedges and broadleaf weeds was considerably lower when compared the treatment of rice straw 7.5 t·ha^{-1} was mulched at 30 DAS with the no mulch treatment (Table 1). When rice straw was spread at a rate of 7.5 t·ha^{-1}, the density of broadleaf weeds, specifically *T. Portulacastrum* (1.97 and 2.04 plants·m^{-2}) *and D. arvensis* (2.02 and 2.03 plants·m^{-2}), was significantly lower in comparison to the no mulch treatment in *kharif* 2020 and *kharif* 2021, respectively. Similarly, rice straw (7.5 t·ha^{-1}) significantly decreased the density of grass weed *E. colona* (1.84 and 1.86 plants·m^{-2}), and also significantly decreased the density of sedge *C. rotundus* (2.01 and 2.03 plants·m^{-2}) in 2020 and 2021, respectively, as compared with the no mulch treatment. Similarly, at 120 days after sowing, mulching with rice straw 7.5 t·ha^{-1} significantly decreased the density of broadleaf weeds, specifically *T. portulacastrum* (2.19 and 2.22 plants·m^{-2}) and *D. arvensis* (2.23 and 2.26 plants·m^{-2}), in comparison to the no mulch treatment in *kharif* 2020 and *kharif* 2021, respectively. Density of grass weed *E. colona* (2.07 and 2.10 plants·m^{-2}) and sedge *C. rotundus* (2.17 and 2.19 plants·m^{-2}) was significantly lower with rice mulch 7.5

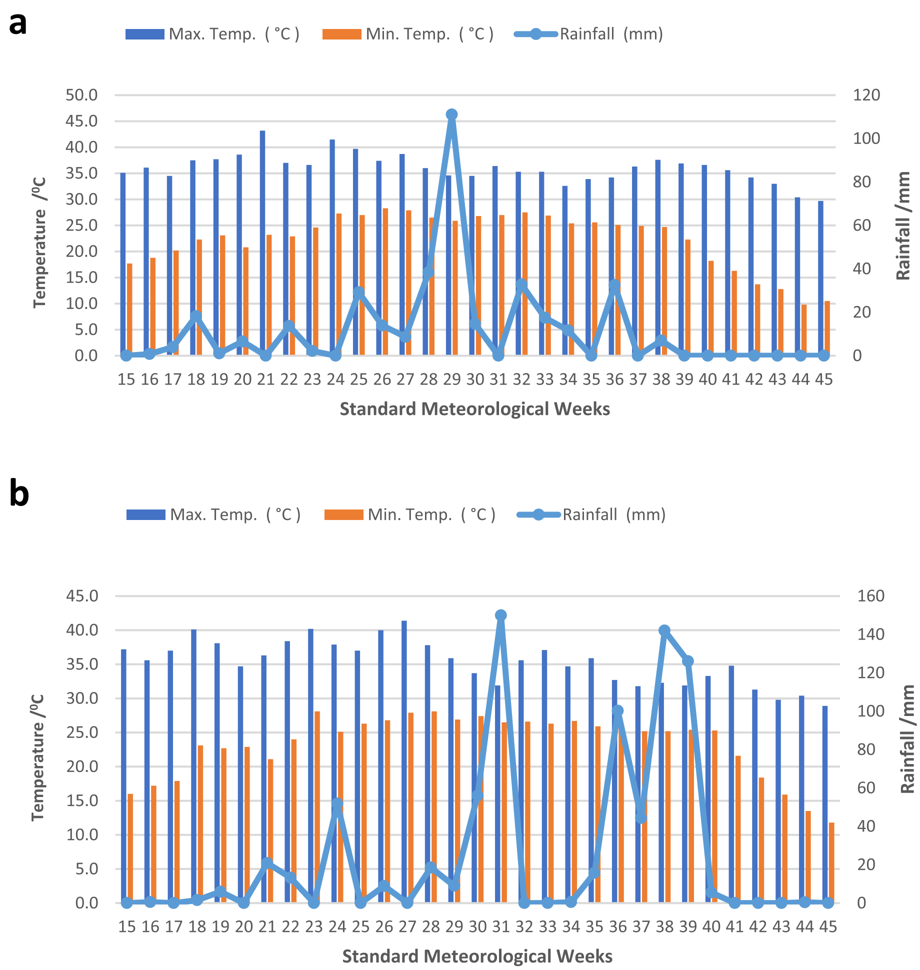

Fig. 1 Mean weekly weather data recorded during (**a**) *kharif* 2020 (**b**) *kharif* 2021

Table 1 Density (plants·m^{-2}) of different weeds as affected by mulching and weed control treatments at 30 DAS

Treatments	Broadleaved Weeds				Grass Weed		Sedge	
	T. portulacastrum		*D. arvensis*		*E. colona*		*C. rotundus*	
	2020	2021	2020	2021	2020	2021	2020	2021
Mulching levels								
No mulch	3.92 a	4.08 a	3.96 a	4.01 a	3.51 a	3.56 a	3.97 a	4.02 a
Mulching with rice straw 7.5 t·ha^{-1}	1.97 b	2.04 b	2.02 b	2.03 b	1.84 b	1.86 b	2.01 b	2.03 b
Weed management								
Untreated control	3.78 a	3.95 a	3.51 a	3.55 a	3.39 a	3.44 a	3.39 a	3.43 a
Weed free	1.00 c	1.00 c	1.00 c	1.00 c	1.00 c	1.00 c	1.00 b	1.00 b
Pendimethalin (Pre) (in a.i.) 1.5 kg·ha^{-1} *fb* two hoeing at 45 & 90 DAS	2.99 b	3.05 b	3.19 b	3.39 ab	2.51 b	2.54 b	3.24 a	3.28 a
Two hoeings at 30 & 60 DAS *fb* quizalofop-p-ethyl 62.5 g·ha^{-1} at 90 DAS	3.55 a	3.70 a	3.35 ab	3.23 b	3.50 a	3.56 a	3.28 a	3.32 a
Two hoeings at 30 & 60 DAS *fb* propaquizafop 50 g·ha^{-1} at 90 DAS	3.56 a	3.72 a	3.27 ab	3.42 ab	3.37 a	3.43 a	3.31 a	3.35 a
Pendimethalin (Pre) 1.5 kg·ha^{-1} *fb* one hoeing at 45 DAS *fb* paraquat 1 kg·ha^{-1} (Shielded spray) at 90 DAS	2.89 b	3.01 b	3.37 ab	3.31 ab	2.36 b	2.40 b	3.37 a	3.40 a
Pendimethalin (Pre) 1.5 kg·ha^{-1} *fb* one hoeing at 45 DAS *fb* glyphosate 2 kg·ha^{-1} (Shielded spray) at 90 DAS	2.88 b	3.01 b	3.22 b	3.26 b	2.58 b	2.62 b	3.34 a	3.38 a

Treatments with same letters are not significantly different among mulching levels or weed management, respectively t·ha^{-1} in *kharif* 2020 and 2021, respectively, as compared with the no mulch treatment (Table 2).

Among the different herbicide treatments, application of pendimethalin (Pre) (in a.i.) 1.5 kg·ha^{-1} had significantly decreased the density of *T. portulacastrum* and *E. colona* at 30 DAS in comparison to the treatments where pendimethalin was not applied, during both the years of study. In case of *D. arvensis* at 30 DAS, significantly reduced density recorded with pendimethalin (Pre) 1.5 kg·ha^{-1} *fb* two hoeing at 45 & 90 DAS (3.19 plants·m^{-2}) during *kharif* 2020 and with two hoeings at 30 & 60 DAS *fb* quizalofop-p-ethyl 62.5 g·ha^{-1} at 90 DAS (3.23 plants·m^{-2}) during *kharif* 2021 in comparison to other treatments. Different herbicide treatments failed to show any effect on the density of *C. rotundus* at 30 DAS as all treatments were statistically at par with untreated control during both years of crop study (Table 1).

Among different herbicidal treatments, treatment which pendimethalin (Pre) 1.5 kg·ha^{-1} *fb* one hoeing at 45 DAS *fb* and glyphosate 2 kg·ha^{-1} (Shielded spray) at 90 DAS was applied had significantly minimum density of *T. portulacastrum* (2.10 and 2.13 plants·m^{-2}, respectively), *D. arvensis* (2.26 and 2.29 plants·m^{-2}, respectively) and *E. colona* (2.61 and 2.64 plants·m^{-2}, respectively) at 120 DAS (Table 2) when compared with the rest of treatments except weed free during both the years of study. In case of *D. arvensis*, statistically comparable results were reported with application of pendimethalin (Pre) 1.5 kg·ha^{-1} *fb* two hoeings at 45 and 90 DAS and pendimethalin (Pre) 1.5 kg·ha^{-1} *fb* one hoeing at 45 DAS *fb* paraquat 1 kg·ha^{-1} (Shielded spray) at 90 DAS. Different herbicide treatments were found effective in reducing the density of *E. colona* significantly in comparison with the untreated control, and all the herbicidal treatments were statistically comparable to each other. Among different herbicides treatments during both years, application of pendimethalin (Pre) 1.5 kg·ha^{-1} *fb* two hoeings at 45 DAS and 90 DAS resulted in significantly lowest density of *C. rotundus*, and it was statistically similar to pendimethalin (Pre) 1.5 kg·ha^{-1} *fb* one hoeing at 45 DAS *fb* paraquat 1 kg·ha^{-1} (shielded spray) at 90 DAS and pendimethalin (Pre) 1.5 kg·ha^{-1} *fb* one hoeing at 45 DAS *fb* glyphosate 2 kg·ha^{-1} (shielded spray) at 90 DAS.

Weed dry weight

During both years of crop experiments, mulching with rice straw at 7.5 t·ha^{-1} recorded the considerably lowest total weed dry weight as compared with no mulch amongst mulching treatments at all crop growth stages (Table 3). In the first and second years of the trial, mulching with rice straw at 7.5 t·ha^{-1} recorded the significantly lowest total weed dry weight (2.59 and 2.65 g·m^{-2}) at 30 DAS as compared with the no mulch treatment (5.37 and 5.50 g·m^{-2}). In k*harif* 2020 and 2021, the total dry weight of weeds was significantly lower at 120 DAS when rice straw mulching at 7.5 t·ha^{-1} (3.72 and 3.77 g·m^{-2}) was applied as compared with the no mulch treatment (6.36 and 6.45 g·m^{-2}), respectively.

The study found that among the weed management levels at 30 DAS, apart from weed free treatment, the treatments with pendimethalin (Pre) (in a.i.) 1.5 kg·ha^{-1} had the lowest total weed dry weight when compared with other treatments in both years of experimentation. Pre-application of pendimethalin 1.5 kg·ha^{-1} *fb* one hoeing

Table 2 Density (plants·m^{-2}) of different weeds as affected by mulching and weed control treatments at 120 DAS

Treatments	Broadleaved Weeds				Grass Weed		Sedge	
	T. portulacastrum		*D. arvensis*		*E. colona*		*C. rotundus*	
	2020	2021	2020	2021	2020	2021	2020	2021
Mulching levels								
No mulch	3.62 a	3.68 a	3.44 a	3.49 a	3.41 a	3.46 a	3.58 a	3.63 a
Mulching with rice straw 7.5 t·ha^{-1}	2.19 b	2.22 b	2.23 b	2.26 b	2.07 b	2.10 b	2.17 b	2.19 b
Weed management								
Untreated control	4.84 a	4.91 a	4.68 a	4.75 a	4.45 a	4.51 a	4.99 a	5.07 a
Weed free	1.00 f	1.00 f	1.00 d	1.00 d	1.00 c	1.00 c	1.00 d	1.00 d
Pendimethalin (Pre) 1.5 kg·ha^{-1} *fb* two hoeings at 45 & 90 DAS	2.87 c	2.91 c	2.38 c	2.42 c	2.87 b	2.91 b	2.41 c	2.43 c
Two hoeings at 30 & 60 DAS *fb* quizalofop-p-ethyl 62.5 g·ha^{-1} at 90 DAS	3.58 b	3.63 b	3.54 b	3.60 b	2.79 b	2.84 b	3.31 b	3.37 b
Two hoeings at 30 & 60 DAS *fb* propaquizafop 50 g·ha^{-1} at 90 DAS	3.52 b	3.57 b	3.68 b	3.73 b	2.85 b	2.89 b	3.34 b	3.39 b
Pendimethalin (Pre) 1.5 kg·ha^{-1} *fb* one hoeing at 45 DAS *fb* paraquat 1 kg·ha^{-1} (Shielded spray) at 90 DAS	2.44 d	2.47 d	2.33 c	2.36 c	2.63 b	2.65 b	2.41 c	2.44 c
Pendimethalin (Pre) 1.5 kg·ha^{-1} *fb* one hoeing at 45 DAS *fb* glyphosate 2 kg·ha^{-1} (Shielded spray) at 90 DAS	2.10 e	2.13 e	2.26 c	2.29 c	2.61 b	2.64 b	2.66 c	2.68 c

Treatments with same letters are not significantly different among mulching levels and Weed management, respectively

Table 3 Total weed dry weight (g·m^{-2}) from different mulching and weed control treatments at 30 and 120 DAS

Treatments	Weed dry Weight (g·m^{-2})			
	30 DAS		120 DAS	
	2020	2021	2020	2021
Mulching levels				
No mulch	5.37 a	5.50 a	6.36 a	6.45 a
Mulching with rice straw 7.5 t·ha^{-1}	2.59 b	2.65 b	3.72 b	3.77 b
Weed management				
Untreated control	4.93 a	5.03 a	8.81 a	8.93 a
Weed free	1.00 c	1.00 c	1.00 e	1.00 e
Pendimethalin (Pre) 1.5 kg·ha^{-1} *fb* two hoeings at 45 & 90 DAS	4.18 b	4.24 b	4.71 c	4.78 c
Two hoeings at 30 & 60 DAS *fb* quizalofop-p-ethyl 62.5 g·ha^{-1} at 90 DAS	4.74 a	4.90 a	6.06 b	6.15 b
Two hoeings at 30 & 60 DAS *fb* propaquizafop 50 g·ha^{-1} at 90 DAS	4.73 a	4.88 a	6.15 b	6.25 b
Pendimethalin (Pre) 1.5 kg·ha^{-1} *fb* one hoeing at 45 DAS *fb* paraquat 1 kg·ha^{-1} (Shielded spray) at 90 DAS	4.14 b	4.25 b	4.29 d	4.35 d
Pendimethalin (Pre) 1.5 kg·ha^{-1} *fb* one hoeing at 45 DAS *fb* glyphosate 2 kg·ha^{-1} (Shielded spray) at 90 DAS	4.15 b	4.24 b	4.27 d	4.32 d

Treatment with same letters are not significantly different among mulching levels and Weed management, respectively

at 45 DAS *fb* glyphosate 2 kg·ha^{-1} (shielded spray) at 90 DAS significantly reduced the total dry weight of weeds at 120 DAS (4.27 and 4.32 g·m^{-2}) in comparison to other treatments but was statistically comparable to application of pendimethalin (Pre) 1.5 kg·ha^{-1} *fb* one hoeing at 45 DAS *fb* paraquat 1 kg·ha^{-1} (shielded spray) at 90 DAS (4.29 and 4.35 g·m^{-2}) (Table 3).

Seed cotton yield

The data revealed that seed cotton yield was higher in 2020 than in 2021. Cotton crop mulching with rice straw 7.5 t·ha^{-1} recorded significantly higher seed cotton yield in first and second year as compared with the no mulch treatment. Among the weed management levels, apart from weed free, cotton treated with pendimethalin (Pre) (in a.i.) 1.5 kg·ha^{-1} *fb* one hoeing at 45 DAS *fb* glyphosate 2 kg·ha^{-1} (Shielded spray) at 90 DAS produced the highest yield (3 324 kg·ha^{-1} and 3 233 kg·ha^{-1}) in both years, which was significantly higher than untreated control (1 841 kg·ha^{-1} and 1 757 kg·ha^{-1}), but statistically at par with all other herbicide treatments (Fig. 2).

Discussion

Weed density was lower in the plots treated with mulching, this might be due to mulching act as a physical barrier in suppressing the emergence of weeds. Pre pendimethalin treatment may have successfully prevented weed seeds from germinating in the early stages and effectively decreased the dynamics of grasses and broadleaf weeds but did not show any effect on the population of *C. rotundus.* Later stages hoeing and application of non-selective herbicides, *i.e.,* paraquat and glyphosate effectively reduced the density of majority of weed species. Similar findings have been reported by Chaudhari et al.(2017), Punia et al. (2019), Grey et al. (2008), Rajanand et al. (2013), and Singh et al. (2016). Pendimethalin, which slows the cell division and root

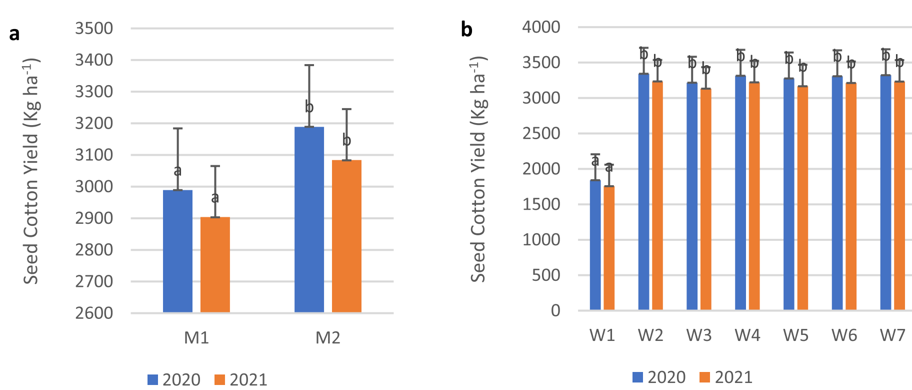

Fig. 2 Effect of mulching (**a**) and weed control (**b**) treatments on seed cotton yield of Bt cotton

and shoot growth of the weeds preventing them from emerging, especially during the vital development phase of cotton, may account for the decrease in weed density under mentioned treatments (Punia et al. 2019; Varsha et al., 2019).

In the *kharif* seasons of 2020 and 2021, there was a considerable difference in rainfall (Fig. 1). Dry weight of weeds was higher in *kharif* 2021 as compared with 2020 which may be due to considerable variation in rainfall during two years (Kaur et al., 2019).

Pre-emergence application of pendimethalin was found effective for the control of weeds as it minimizes the early weed competition, however the pre-emergence herbicide loses its efficacy after few weeks, thus the problem of late emerging weeds becomes more serious. To manage late emerging weeds during cotton growth period, manual or chemical methods, selective post emergence herbicides "fops" and direct spray of glyphosate and paraquat are effective to control weeds in cotton field. These results are in line with Punia et al. (2019), Kamble et al. (2017), Singh et al. (2016), Chaudhari et al. (2017), and Veeraputhiran et al. (2015).

Decrease in cotton yield is primarily caused by intense weed competition during the early stages. Compared with crops, weeds gathered a higher concentration of mineral nutrients and quickly depleting soil nutrients, and had a negative impact on seed cotton output (Mukhtar et al., 2006; Kaur et al., 2019; Prabhu, 2010). Mulching can provide favourable environment to crop and hindrance to weed growth.

Conclusion

Study demonstrates that mulching with rice straw 7.5 t·ha^{-1} along with application of pendimethalin (Pre) (in a.i.) 1.5 kg·ha^{-1} *fb* one hoeings at 45 *fb* Glyphosate 2 kg·ha^{-1} (Shielded spray) at 90 DAS is a viable option for effective control of grassy and broadleaf weeds in Bt cotton field in northwest of India.

Abbreviations

DAS Days after sowing
fb Followed by
PRE Pre-emergence

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s42397-024-00199-6.

Additional file 1: Table S1 Complete analysis of variance (ANOVA) tests.

Acknowledgements
We would like to thank CCS Haryana Agricultural University, Hisar, Haryana for providing facilities for conducting this research.

Authors' contributions
Priyanka D: Conceptualization; writing original draft. Karmal S: Conceptualization, Methodology development, Supervision. Meena S: Investigation, Conceptualization. Sushil K: Statistical analyzing, Writing and investigation.

Funding
No funding was received.

Data availability
Data supporting the findings is available.

Declarations

Ethics approval and consent to participate
Not Applicable.

Consent for publication
Not Applicable.

Competing interests
The authors declare no conflicts of interest.

Received: 21 January 2024 Accepted: 22 August 2024
Published online: 11 November 2024

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