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Impact of weed management practices on weed control efficiency and fibre quality in cotton under the high-density planting system

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Abstract

Cotton enjoyed the synonyms 'White Gold,' 'King of Fibre Crops,' and 'Friendly Fibre', playing a vital role as both a cash and fibre crop in India. However, weeds pose a major challenge, causing an approximate 45% yield reduction in cotton nationwide. Effective weed management is crucial for optimizing cotton yield and fibre quality. This study evaluated the impact of various weed management practices on productivity and fibre quality. Field trials were conducted using multiple treatments, including pre-and post-emergence herbicides, hand weeding, and power weeding. Fibre quality parameters, such as fibre length, strength, fineness, micronaire, and elongation percentage, were measured across treatments. While results showed no significant differences in fibre quality among the treatments, the combination of preemergence (PE) application of Pendimethalin at the rate of 1.0 kg active ingredient ha^{-1} + Metolachlor at the rate of 1.0 kg active ingredient ha^{-1} followed by post-emergence (POE) application of Pyrithiobac sodium at the rate of 0.075 kg active ingredient ha^{-1} + quizalofop ethyl at the rate of 0.075 kg active ingredient ha^{-1} emerged as the most effective weed control strategy.This treatment provided effective weed suppression, reduced competition for resources, and resulted in a higher seed cotton yield than other treatments. The study concluded that, although fibre quality did not vary significantly, the integrated use of Pendimethalin and Metolachlor as preemergence herbicides and Pyrithiobac sodium and quizalofop ethyl as post-emergence herbicides offers an optimal solution for cotton growers.

Keywords

cotton; fibre quality; weed management; yield

Introduction

Cotton is a soft, white fibre that develops inside a protective boll, surrounding the seeds of the cotton plant, giving it a fluffy appearance. Cotton is called 'white gold' and has manifold usage in the cotton-based industries (1). Only four of the 53 *Gossypium* species found worldwide are cultivated in India. There are two Asiatic cotton species, *viz*., *Gossypium arboreum* and *Gossypium herbaceum;* one American Upland cotton, *viz*., *Gossypium hirsutum;* and *Gossypium barbadense,* which is called Egyptian cotton. *G. hirsutum* is the most extensively cultivated, representing approximately 88% of the hybrid cotton grown in India in 2018-19. Moreover, nearly all Bt cotton hybrids in the country belong to the *G. hirsutum* variety, making up 90% of the total cotton cultivation (2, 3).

In the 2023-2024 season, India cultivated cotton over 12.68 million hectares, producing 32.52 million bales with a productivity of 436 kg/ha. In Tamil Nadu, 0.13 million hectares produced 0.28 million bales, with a productivity of 363.54 kg/ha (4). Cotton fibre is a predominant raw material for the garment industry, offering a source of revenue for about 6 million farmers in India and creating employment for 50 million people (5). It plays a vital role in the global economy, accounting for over half of the total textile production. Besides its fibre, cotton is an important supplier of edible oil, rich in many essential fatty acids, *viz*., linoleic, myristic, oleic, palmitic, palmitoleic, and stearic acids. An insufficiency of these acids may cause artery constriction, which reduces the heart's blood supply (6). Although several reasons contribute to the decline in cotton production, weeds primarily reduce cotton yield by up to 85% (7).

The period in the crop growth cycle during which weeds need to be controlled to avoid intolerable yield losses is the critical period for weed control (CPWC) (8). The crop yield obtained by proper weeding during this period is almost equal to that obtained under weed-free conditions for the entire season.

The CPWC for cotton, spanning 30 to 60 days, is critical for preventing yield losses caused by weed interference (9). Farmers utilize various weed control methods to address these unwanted plants, including mechanical, biological, chemical, and allelopathic approaches (10). As a result of labor scarcity and growing labor expenses, herbicidal weed control using herbicides like Pendimethalin, Metolachlor and Pyrithiobac sodium is required during the most severe stage of weed infestation (11).

Manual hand weeding is labor-intensive and time-consuming due to the extensive area requiring coverage. Farmers face many difficulties associated with a shortage of manpower and escalating wages. Herbicide expenses can occasionally be lower than the costs associated with manual weeding. In these circumstances, herbicide application is significantly secure and economically viable for weed management. Additionally, there have only been limited studies that examined pre- and post-emergence treatment, hand weeding, and power weeding in cotton, particularly under the high-density planting system (HDPS), which is now getting more prevalent (12).

In light of this, the present study was initiated with the following objectives: to identify an effective weed management strategy to control weeds and determine cotton yield and fibre quality under HDPS.

Materials and Methods

The field experiment was conducted at the Cotton Research Station, Veppanthattai, situated in the Veppanthattai block of the Perambalur district during the summer of 2024. The site of experimentation resides 149 meters above mean sea level at latitude 11° 32' N and longitude 78° 83' E. The experimental field comprises deep, calcareous, clayey, moderately well-drained, and slowly permeable soil.

Experiment details

As the test crop, the cotton variety VPT 2 had been selected and hand sown employing a 90 x 15 cm spacing that performs effectively for HDPS. VPT 2 was chosen for this study as it is a compact cotton variety with synchronized boll maturity and bursting. The field study used Randomized Block Design (RBD), featuring ten treatments and three replications. The treatment details are as follows:

T_1: Preemergence (PE) Pendimethalin at the rate of 1.0 kg active ingredient ha^{-1} 3 days after sowing (DAS) followed by hand weeding (HW) once at 45 DAS

T_2: PE Pendimethalin at the rate of 1.0 kg active ingredient ha^{-1} followed by Post Emergence (POE) Pyrithiobac sodium at the rate of 0.075 kg active ingredient ha^{-1} + Quizalofop ethyl at the rate of 0.075 kg active ingredient ha^{-1} 45 DAS

T_3: PE Pendimethalin at the rate of 1.0 kg active ingredient ha^{-1} followed by weeding by Power Weeder (PW) at 45 DAS

T_4: PE Pendimethalin at the rate of 1.0 kg active ingredient ha^{-1} + Metolachlor at the rate of 1.0 kg active ingredient ha^{-1} followed by HW at 45 DAS

T_5: PE Pendimethalin at the rate of 1.0 kg active ingredient ha^{-1} + Metolachlor at the rate of 1.0 kg ha^{-1} followed by POE Pyrithiobac sodium at the rate of 0.075 kg active ingredient ha^{-1} + Quizalofop ethyl at 0.075 kg active ingredientha^{-1} 45 DAS

T_6: PE Pendimethalin at the rate of 1.0 kg active ingredient ha^{-1} + Metolachlor at 1.0 kg active ingredient ha^{-1} followed by PW at 45 DAS

T_7: PE Pendimethalin at the rate of 1.0 kg active ingredientha^{-1} followed by PW at 25 and 45 DAS

T_8: PE Pendimethalin at the rate of 1.0 kg active ingredient ha^{-1} + Metolachlor at the rate of 1.0 kg active ingredient ha^{-1} followed by PW at 25 and 45 DAS

T_9: Weed-free check

T_{10}: Unweeded control

Observation on weeds

Weed density and dry weight: The total weed density and weed dry weight were observed at three stages, *viz*., 20, 40, and 60 DAS. Quadrates measuring 0.25 m^2 were used to measure the weed density at four locations within each plot. The mean values were then represented in number m^{-2}. The total dry weight of the weeds was measured in g m^{-2} after they were shade-dried and then dried in a hot air oven at 80°C until they reached a consistent weight.

Weed density and dry weight data were statistically examined after undergoing square root transformation ($\sqrt{X+0.5}$) due to their significant variance (13). For comparison, the critical difference (CD) was computed using the analysis of variance (ANOVA) method at the five percent probability level.

Weed control efficiency (WCE): Weed Control Efficiency (WCE) was calculated at 20, 40 and 60 DAS as suggested previously (14):

$$WCE = [(W1-W2)/W1] \times 100 \quad \text{(Eqn.1)}$$

Where,

W1- Dry weight of total weeds recorded in the unweeded control plot (g m^{-2})

W2- Dry weight of total weeds recorded in the treated plot (g m^{-2})

Weed Index (WI): The weed index was computed using a standard methodology (15):

$$\text{Weed Index (WI) \%} = [(X-Y)/X] \times 100 \quad \text{(Eqn.2)}$$

Where,

X = Yield recorded in the minimum competition plot

Y = Yield recorded in the treated plot for which the WI has to be calculated.

Observation on seed cotton yield

The seed cotton yield obtained from the net plot area from three replications was picked by hand, shade dried, and the weight was recorded. This total weight was then expressed in kilograms per hectare (kg ha^{-1}).

Quality characteristics of cotton

Ginning percentage: Ginning percentage was determined by dividing the weight of lint by seed cotton (16).

Seed index: The weight of one hundred seeds, randomly selected after ginning, was recorded and expressed in grams.

Lint index: The weight obtained from ginning one hundred cotton seeds was recorded, weighed, and expressed in grams.

Fibre quality: Fibre length, fibre strength, uniformity ratio, micronaire and elongation percentage were assessed using a state-of-the-art high-volume instrument (HVI) situated at the Central Institute for Research on Cotton Technology, ICAR Regional Unit, in Coimbatore, Tamil Nadu, 641 003, India. For each plot, 200 grams of fibre samples were processed and conditioned per standard practice. The Universal HVI Micronaire Calibration Cotton Standards were used for micronaire as per the instruction manual.

Results and Discussion

Impact of different weed management practices on weed dynamics in cotton under HDPS

Weed species associated with cotton cultivation: The experimental field was overrun by 14 weed species across 7 distinct plant families. The observed grass species were *Cynodon dactylon, Chloris barbata, Echinochloa colona,* and *Brachiaria reptans*, along with two types of sedges, *Cyperus iria* and *Cyperus rotundus*. Among broad-leaved weeds, *Abutilon indicum, Acalypha indica, Corchorus trilocularis, Euphorbia heterophylla, Euphorbia hirta, Parthenium hysterophorus, Phyllanthus maderaspatensis,* and *Trianthema portulacastrum* invade the experimental field. Similar weed composition in cotton has been reported by earlier studies (17, 18).

Total weed density: Weed density varied significantly across weed management practices at all observation stages (Table 1). The weed-free check (T_9) consistently showed no weed density.

At 20 DAS, PE Pendimethalin at 1.0 kg active ingredient ha^{-1} + Metolachlor at the rate of 1.0 kg active ingredient ha^{-1} followed by POE Pyrithiobac sodium at the rate of 0.075 kg active ingredient ha^{-1} + Quizalofop ethyl at 0.075 kg active ingredient ha^{-1} (T_5) recorded the lowest weed density (13.04 m^{-2}). However, it was similar to PE Pendimethalin at 1.0 kg active ingredient ha^{-1} + Metolachlor at the rate of 1.0 kg active ingredient ha^{-1} followed by PW at the rate of 45 DAS (T_6) with the density of 13.60 m^{-2}. This may be attributed to the effective weed control achieved in the early stages through preemergence herbicides, as reported previously (19).

At 40 DAS, the treatment, PE Pendimethalin at 1.0 kg active ingredient ha^{-1} + Metolachlor at 1.0 kg active ingredient ha^{-1} followed by POE Pyrithiobac sodium at 0.075 kg active ingredient ha^{-1} + Quizalofop ethyl at 0.075 kg active ingredient ha^{-1} (T_5), resulted in a lower weed density of 17.20 m^{-2}, followed by preemergence application of 1.0 kg active ingredient ha^{-1} of Pendimethalin + Metolachlor at 1.0 kg active ingredient ha^{-1} followed by PW at 25 & 45 DAS (T_8) (29.65 m^{-2}). This is primarily due to the inhibition of acetolactate synthase (ALS) by post-emergence Pyrithiobac sodium. At the same time, Quizalofop ethyl inhibits fatty acid synthesis through acetyl-CoA carboxylase (ACCase) inhibition (11), significantly reducing both grassy and broadleaf weeds.

At 60 DAS, the lowest weed density was seen in preemergence application of 1.0 kg active ingredient ha^{-1} of Pendimethalin + Metolachlor at 1.0 kg active ingredient ha^{-1} followed by POE Pyrithiobac sodium at 0.075 kg active ingredient ha^{-1} + Quizalofop ethyl at 0.075 kg active ingredient ha^{-1} (T_5) (25.38 m^{-2}). However, it was on par with PE Pendimethalin at the rate of 1.0 kg active ingredient ha^{-1} + Metolachlor at the rate of 1.0 kg active ingredient ha^{-1} followed by POE Pyrithiobac sodium at the rate of 0.075 kg active ingredient ha^{-1} + Quizalofop ethyl at the rate of 0.075 kg active ingredient ha^{-1} (T_2) (37.15 m^{-2}). This could be due to Pendimethalin being absorbed by grasses through coleoptiles and seedling shoots below ground level, leading to rapid depletion of carbohydrate reserves in weeds through accelerated respiration (19). Additionally, Metolachlor inhibits the synthesis of chlorophyll, proteins, and fatty acids in weeds, ultimately reducing weed density. The highest weed density (46.75, 80.85, and 117.15 m^{-2} at 20, 40, and 60 DAS, respectively) was observed in the unweeded control (T_{10}).

Weed dry weight: Different weed management practices significantly influenced the total dry weight of weeds at

Table 1. Effect of weed management practices on total weed density in HDPS cotton

Treatments		Total weed density (No. m^{-2})		
		20 DAS	**40 DAS**	**60 DAS**
T_1	PE Pendimethalin at the rate of 1.0 kg active ingredient ha^{-1} followed by HW at the rate of 45th DAS	4.77 (22.28)	8.28 (68.32)	9.79 (95.65)
T_2	PE Pendimethalin at the rate of 1.0 kg active ingredient ha^{-1} followed by POE Pyrithiobac sodium 0.075 kg active ingredient ha^{-1} + Quizalofop ethyl at the rate of 0.075 g active ingredient ha^{-1}	4.29 (17.96)	6.07 (36.46)	6.13 (37.15)
T_3	PE Pendimethalin at the rate of 1.0 kg active ingredient ha^{-1} followed by PW at the rate of 45 DAS	4.66 (21.35)	7.96 (63.18)	9.12 (83.24)
T_4	PE Pendimethalin at the rate of 1.0 kg active ingredient ha^{-1} + Metolachlor at the rate of 1.0 kg active ingredient ha^{-1} followed by HW at the rate of 45 DAS	3.89 (14.64)	6.85 (46.45)	9.09 (82.21)
T_5	PE Pendimethalin at the rate of 1.0 kg active ingredient ha^{-1} + Metolachlor at the rate of 1.0 kg active ingredient ha^{-1} followed by POE Pyrithrobac sodium at the rate of 0.075 kg active ingredient ha^{-1} + Quizalofop ethyl at the rate of 0.075 kg active ingredient ha^{-1}	3.68 (13.04)	4.20 (17.20)	5.08 (25.38)
T_6	PE Pendimethalin at the rate of 1.0 kg active ingredient ha^{-1} + Metolachlor at the rate of 1.0 kg active ingredient ha^{-1} followed by PW at the rate of 45 DAS	3.75 (13.60)	6.51 (41.97)	7.65 (58.16)
T_7	PE Pendimethalin at the rate of 1.0 active ingredient ha^{-1} followed by PW at the rate of 25 & 45 DAS	4.54 (20.19)	6.97 (48.37)	7.95 (62.95)
T_8	PE Pendimethalin at the rate of 1.0 kg active ingredient ha^{-1} + Metolachlor at the rate of 1.0 kg active ingredient ha^{-1} followed by PW at the rate of 25 & 45 DAS	3.86 (14.46)	5.48 (29.65)	6.71 (44.75)
T_9	Weed free check	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
T_{10}	Unweeded Control	6.86 (46.75)	9.01 (80.85)	10.83 (117.15)
	SEd	0.25	0.38	0.45
	CD (p=0.05)	0.52	0.80	0.95

Figures in parentheses are original values which were transferred into √(x + 0.5)
PE- pre emergence, POE- post emergence, HW- hand weeding, PW- power weeding.

Table 2. Effect of weed management practices on total weed dry weight in HDPS cotton

Treatments		Total weed dry weight (g m^{-2})		
		20 DAS	**40 DAS**	**60 DAS**
T_1	PE Pendimethalin at the rate of 1.0 kg active ingredient ha^{-1} followed by HW at the rate of 45th DAS	4.96 (24.21)	7.02 (48.96)	8.55 (72.86)
T_2	PE Pendimethalin at the rate of 1.0 kg active ingredient ha^{-1} followed by POE Pyrithiobac sodium 0.075 kg active ingredient ha^{-1} + Quizalofop ethyl at the rate of 0.075 g active ingredient ha^{-1}	5.28 (27.39)	3.95 (15.16)	5.06 (25.13)
T_3	PE Pendimethalin at the rate of 1.0 kg active ingredient ha^{-1} followed by PW at the rate of 45 DAS	5.08 (25.47)	6.70 (44.61)	8.23 (67.79)
T_4	PE Pendimethalin at the rate of 1.0 kg active ingredient ha^{-1} + Metolachlor at the rate of 1.0 kg active ingredient ha^{-1} followed by HW at the rate of 45 DAS	4.14 (16.68)	5.92 (34.56)	7.23 (51.78)
T_5	PE Pendimethalin at the rate of 1.0 kg active ingredient ha^{-1} + Metolachlor at the rate of 1.0 active ingredient ha^{-1} followed by POE Pyrithrobac sodium at the rate of 0.075 kg active ingredient ha^{-1} + Quizalofop ethyl at the rate of 0.075 kg active ingredient ha^{-1}	3.57 (12.29)	2.90 (7.93)	4.48 (19.58)
T_6	PE Pendimethalin at the rate of 1.0 kg active ingredient ha^{-1} + Metolachlor at the rate of 1.0 kg active ingredient ha^{-1} followed by PW at the rate of 45 DAS	4.40 (18.91)	6.34 (39.82)	6.74 (44.96)
T_7	PE Pendimethalin at the rate of 1.0 kg active ingredient ha^{-1} followed by PW at the rate of 25 & 45 DAS	5.39 (28.64)	5.28 (27.49)	5.68 (31.96)
T_8	PE Pendimethalin at the rate of 1.0 kg active ingredient ha^{-1} + Metolachlor at the rate of 1.0 kg active ingredient ha^{-1} followed by PW at the rate of 25 & 45 DAS	3.10 (9.18)	4.85 (23.15)	5.43 (29.11)
T_9	Weed free check	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
T_{10}	Unweeded Contro	6.46 (41.37)	8.42 (70.57)	10.67 (113.62)
	SEd	**0.26**	**0.33**	**0.39**
	CD (p=0.05)	**0.54**	**0.69**	**0.83**

Figures in parentheses are original values which were transferred into √(x + 0.5)
PE- pre emergence, POE- post emergence, HW- hand weeding, PW- power weeding.

each of the three observation stages. At 20, 40, and 60 DAS, the weed-free check (T_9) recorded no weed dry weight (Table 2).

At 20 DAS, preemergence application of each of 1.0 kg active ingredient ha^{-1} of Pendimethalin + Metolachlor followed by PW at the rate of 25 & 45 DAS (T_8) recorded a significantly lower total weed dry weight (9.18 g m^{-2}), which was similar to the preemergence application of 1.0 kg active ingredient ha^{-1} of Pendimethalin + Metolachlor, combined with post emergence application of 0.075 kg active ingredient ha^{-1} of

Pyrithiobac sodium and Quizalofop ethyl (T_5), with a weight of 12.29 g m^{-2}.

At 40 DAS, the lowest weed dry weight of 7.93 g m^{-2} was recorded in the preemergence application of 1.0 kg active ingredient ha^{-1} of Pendimethalin + Metolachlor at the rate of 1.0 kg active ingredient ha^{-1} followed by POE Pyrithiobac sodium at the rate of 0.075 kg active ingredient ha^{-1} and Quizalofop ethyl at the rate of 0.075 kg active ingredient ha^{-1} (T_5). The next lowest weed dry weight (15.16 g m^{-2}) was recorded with the preemergence application of 1.0 kg active ingredient ha^{-1} of Pendimethalin followed by POE Pyrithiobac sodium at the rate of 0.075 kg active ingredient ha^{-1} + Quizalofop ethyl at the rate of 0.075 kg active ingredient ha^{-1} (T_2).

At 60 DAS, the lowest weed dry weight of 19.58 g m^{-2} was recorded in the preemergence application of 1.0 kg active ingredient ha^{-1} each of Pendimethalin and Metolachlor followed by post-emergence application of 0.075 kg active ingredient ha^{-1} of Pyrithiobac sodium and Quizalofop ethyl (T_5). This result was on par with PE Pendimethalin at the rate of 1.0 kg active ingredient ha^{-1} followed by POE Pyrithiobac sodium at the rate of 0.075 kg active ingredient ha^{-1} + Quizalofop ethyl at the rate of 0.075 kg active ingredient ha^{-1} (T_2) recorded a weed dry weight of 25.13 g m^{-2}. The preemergence application of Pendimethalin combined with Metolachlor resulted in lower total weed dry weight, demonstrating its effectiveness in weed control across all growth stages. Likewise, the post-emergent application of Pyrithiobac sodium and Quizalofop ethyl effectively managed the second wave of emerging weeds. These herbicides provided control for up to 60-75 days. These findings are consistent with the previous studies (20, 21). The highest weed dry weight was recorded in the unweeded control (T_{10}) (41.37, 70.57, and 113.62 g m^{-2} at 20, 40, and 60 DAS, respectively).

Weed Control Efficiency (WCE): Various weed control treatments significantly influenced the weed control efficiency (WCE) at different stages of observation (Table 3). At 20, 40, and 60 DAS, the weed-free check (T_9) achieved the highest WCE at 100%.

Among the weed management treatments, preemergence application of 1.0 kg active ingredient ha^{-1} each of Pendimethalin and Metolachlor + PW at the rate of 25 and 45 DAS (T_8) recorded a higher WCE of 77.81%, followed by PE Pendimethalin at the rate of 1.0 kg active ingredient ha^{-1} + Metolachlor at the rate of 1.0 kg ha^{-1} followed by POE Pyrithiobac sodium at the rate of 0.075 kg active ingredient ha^{-1} + Quizalofop ethyl at the rate of 0.075 kg active ingredient ha^{-1} (T_5) with a WCE of 70.29%.

At 40 and 60 DAS, among the weed management treatments, preemergence application of 1.0 kg active ingredient ha^{-1} each of Pendimethalin and Metolachlor followed by post emergence application of 0.075 kg active ingredient ha^{-1} of Pyrithiobac sodium and Quizalofop ethyl (T_5) achieved a high WCE of 88.76 and 82.77%, respectively, followed by pre-emergence application of 1.0 kg active ingredient ha^{-1} each of Pendimethalin and Metolachlor followed by POE Pyrithiobac sodium at the rate of 0.075 kg active ingredient ha^{-1} + Quizalofop ethyl at the rate of 0.075 kg active ingredient ha^{-1} (T_2) with 78.52 and 77.88%, respectively. The reduction in weed competition, achieved by successfully managing the first and second flushes of weeds, likely led to a decrease in overall weed density and dry weight. The application of both preemergence (Pendimethalin + Metolachlor) and post-emergence (Pyrithiobac sodium + Quizalofop ethyl) effectively minimized weed biomass (22). A similar result was obtained from another experiment (23). The unweeded control (T_{10}) recorded zero WCE at all the stages of observation.

Weed index (WI): The weed index (WI), which measures the proportion of yield reduction due to weed competition, was calculated using the weed-free check (T_9), as the baseline, which represented zero weed competition and produced the highest seed cotton yield (Table 3). This treatment was used as the baseline for calculating the weed index.

The treatment preemergence application of 1.0 kg active ingredient ha^{-1} each of Pendimethalin and Metolachlor followed by post-emergence application of 0.075 kg active ingredient ha^{-1} of Pyrithiobac sodium and Quizalofop ethyl (T_5) resulted in the lowest WI of 3.03%, followed by preemergence application of 1.0 kg active ingredient ha^{-1} each of Pendimethalin and Metolachlor + PW at the rate of 25 & 45 DAS (T_8) with 10.16%. The lower weed index in these treatments was attributed to more effective weed control, leading to higher seed cotton yields. These findings are in line with (20, 24). The unweeded control (T_{10}) exhibited the highest weed index of 69.46%.

Impact of different weed management practices on seed cotton yield under HDPS

Seed cotton yield: The weed free-check (T_9) recorded the highest seed cotton yield of 2163 kg ha^{-1}, statistically similar to the yield from the pre-emergence application of 1.0 kg active ingredient ha^{-1} each of Pendimethalin and Metolachlor followed by post-emergence application of 0.075 kg active ingredient ha^{-1} of Pyrithiobac sodium and Quizalofop ethyl (T_5) resulted in 2098 kg ha^{-1} (Table 4). This is primarily due to the use of PE Pendimethalin and Metolachlor at 3 DAS, which effectively controls the initial flush of weeds by inhibiting cell division through micro-tubule entry and inhibiting chlorophyll synthesis, reducing weed density, nutrient depletion, and dry weight, thereby enhancing crop growth and cotton yield (21). The PoE application of Pyrithiobac sodium + Quizalofop ethyl

Table 3. Effect of weed management practices on total weed control efficiency and weed index in HDPS cotton

contr

	Treatments	WCE (%)			WI (%)
		20 DAS	40 DAS	60 DAS	
T_1	PE Pendimethalin at the rate of 1.0 kg active ingredient ha^{-1} followed by HW at the rate of 45 DAS	41.47	30.62	35.87	44.58
T_2	PE Pendimethalin at the rate of 1.0 kg active ingredient ha^{-1} followed by POE Pyrithiobac sodium 0.075 kg active ingredient ha^{-1} + Quizalofop ethyl at the rate of 0.075 g active ingredient ha^{-1}	33.79	78.52	77.88	40.96
T_3	PE Pendimethalin at the rate of 1.0 kg active ingredient ha^{-1} followed by PW at the rate of 45 DAS	38.43	36.79	40.42	36.77
T_4	PE Pendimethalin at the rate of 1.0 kg active ingredient ha^{-1} + Metolachlor at the rate of 1.0 active ingredient ha^{-1} followed by HW at the rate of 45 DAS	59.68	51.03	54.43	21.10
T_5	PE Pendimethalin at the rate of 1.0 kg active ingredient ha^{-1} + Metolachlor at the rate of kg active ingredient ha^{-1} followed by POE Pyrithrobac sodium at the rate of 0.075 kg active ingredient ha^{-1} + Quizalofop ethyl at the rate of 0.075 kg active ingredient ha^{-1}	70.29	88.76	82.77	3.03
T_6	PE Pendimethalin at the rate of 1.0 kg active ingredient ha^{-1} + Metolachlor at the rate of 1.0 kg active ingredient ha^{-1} followed by PW at the rate of 45 DAS	54.29	43.57	60.43	15.68
T_7	PE Pendimethalin at the rate of 1.0 kg active ingredient ha^{-1} followed by PW at the rate of 25 & 45 DAS	30.77	61.05	71.87	40.89
T_8	PE Pendimethalin at the rate of 1.0 kg active ingredient ha^{-1} + Metolachlor at the rate of 1.0 kg active ingredient ha^{-1} followed by PW at the rate of 25 & 45 DAS	77.81	67.20	74.38	10.16
T_9	Weed free check	100	100	100	-
T_{10}	Unweeded Control	-	-	-	69.46

Data not statistically analyzed
PE- pre emergence, POE- post emergence, HW- hand weeding, PW- power weeding.

Table 4. Effect of weed management practices on seed cotton yield and quality parameters *viz.* ginning percentage, seed index and lint index of cotton under HDPS

	Treatments	Seed cotton yield (kg ha^{-1})	Quality parameters		
			Ginning %	Lint index	Seed index
T_1	PE Pendimethalin at the rate of 1.0 kg active ingredient ha^{-1} followed by HW at the rate of 45 DAS	1178	32.29	3.48	9.50
T_2	PE Pendimethalin at the rate of 1.0 kg active ingredient ha^{-1} followed by POE Pyrithiobac sodium 0.075 kg active ingredient ha^{-1} + Quizalofop ethyl at the rate of 0.075 g active ingredient ha^{-1}	1275	32.67	3.49	9.51
T_3	PE Pendimethalin at the rate of 1.0 kg active ingredient ha^{-1} followed by PW at the rate of 45 DAS	1368	32.25	3.32	9.45
T_4	PE Pendimethalin at the rate of 1.0 kg active ingredient ha^{-1} + Metolachlor at the rate of 1.0 kg active ingredient ha^{-1} followed by HW at the rate of 45 DAS	1685	32.98	3.38	9.57
T_5	PE Pendimethalin at the rate of 1.0 kg active ingredient ha^{-1} + Metolachlor at the rate of 1.0 active ingredient ha^{-1} followed by POE Pyrithiobac sodium at the rate of 0.075 kg active ingredient ha^{-1} + Quizalofop ethyl at the rate of 0.075 kg active ingredient ha^{-1}	2098	32.55	3.43	9.52
T_6	PE Pendimethalin at the rate of 1.0 kg active ingredient ha^{-1} + Metolachlor at the rate of 1.0 kg active ingredient ha^{-1} followed by PW at the rate of 45 DAS	1819	32.61	3.53	9.50
T_7	PE Pendimethalin at the rate of 1.0 kg active ingredient ha^{-1} followed by PW at the rate of 25 & 45 DAS	1281	32.42	3.26	9.73
T_8	PE Pendimethalin at the rate of 1.0 kg active ingredient ha^{-1} + Metolachlor at the rate of 1.0 kg active ingredient ha^{-1} followed by PW at the rate of 25 & 45 DAS	1954	32.36	3.37	9.49
T_9	Weed free check	2163	32.55	3.57	9.47
T_{10}	Unweeded Control	649	32.77	3.28	9.46
	SEd	**53.7**	**0.24**	**0.21**	**0.23**
	CD (p=0.05)	**112.7**	**NS**	**NS**	**NS**

Data not statistically analyzed
PE- pre emergence, POE- post emergence, HW- hand weeding, PW- power weeding.

Table 5. Effect of weed management practices on quality parameters of cotton under HDPS

	Treatments	Fibre length (mm)	Fibre strength (g tex^{-1})	Elongation (%)	Uniformity ratio	Micronaire (10^{-6} inch^{-1})
T_1	PE Pendimethalin at the rate of 1.0 kg active ingredient ha^{-1} followed by HW at the rate of 45 DAS	27.77	26.73	6.03	82.33	3.40
T_2	PE Pendimethalin at the rate of 1.0 kg active ingredient ha^{-1} followed by POE Pyrithiobac sodium 0.075 kg active ingredient ha^{-1} + Quizalofop ethyl at the rate of 0.075 g active ingredient ha^{-1}	28.10	28.53	5.97	83.00	3.47
T_3	PE Pendimethalin at the rate of 1.0 kg active ingredient ha^{-1} followed by PW at the rate of 45 DAS	27.93	28.57	6.03	82.33	3.43
T_4	PE Pendimethalin at the rate of 1.0 kg active ingredient ha^{-1} + Metolachlor at the rate of 1.0 kg active ingredient ha^{-1} followed by HW at the rate of 45 DAS	27.67	27.40	6.03	82.33	3.57
T_5	PE Pendimethalin at the rate of 1.0 kg active ingredient ha^{-1} + Metolachlor at the rate of 1.0 kg active ingredient ha^{-1} followed by POE Pyrithiobac sodium at the rate of 0.075 kg active ingredient ha^{-1} + Quizalofop ethyl at the rate of 0.075 kg active ingredient ha^{-1}	27.67	27.20	6.07	83.00	3.50
T_6	PE Pendimethalin at the rate of 1.0 kg active ingredient ha^{-1} + Metolachlor at the rate of 1.0 kg active ingredient ha^{-1} followed by PW at the rate of 45 DAS	27.53	27.67	6.03	82.67	3.30
T_7	PE Pendimethalin at the rate of 1.0 kg active ingredient ha^{-1} followed by PW at the rate of 25 & 45 DAS	27.90	27.20	5.97	82.67	3.57
T_8	PE Pendimethalin at the rate of 1.0 kg active ingredient ha^{-1} + Metolachlor at the rate of 1.0 kg active ingredient ha^{-1} followed by PW at the rate of 25 & 45 DAS	28.47	28.53	6.00	82.67	3.40
T_9	Weed free check	28.27	27.40	5.97	83.33	3.43
T_{10}	Unweeded Control	27.10	25.63	5.83	82.00	3.20
SEd		0.40	0.91	0.12	0.78	0.17
CD (p=0.05)		NS	NS	NS	NS	NS

PE- pre emergence, POE- post emergence, HW- hand weeding, PW- power weeding.

olled the second weed flush and further minimized competition from grassy and broadleaf weeds. Sequential application of both herbicides during the critical growth period allowed for better resource use and nutrient uptake, ultimately improving seed cotton yield (22). The unweeded control (T_{10}) had the lowest seed cotton yield of 649 kg ha^{-1}.

Impact of different weed management practices on quality parameters of cotton under HDPS

No significant differences were observed in ginning percentage, seed index, and lint index among the various weed management techniques in cotton under HDPS (Table 4).

Impact of different weed management practices on fibre quality of cotton under HDPS

There were no significant differences in fibre quality among the different weed management approaches under HDPS (Table 5).

Conclusion

From this study, it could be concluded that preemergence application of each of 1.0 kg active ingredient ha^{-1} of Pendimethalin and Metolachlor, followed by post-emergence application of Pyrithiobac sodium at 0.075 kg active ingredient ha^{-1}+ Quizalofop ethyl at 0.075 kg active ingredient ha^{-1} resulted in increased WCE and seed cotton yield. It also led to lower weed density, dry weight, and weed index of cotton under HDPS, and it did not alter the cotton fibre quality. Therefore, chemical weed management by combining preemergence and post-emergence herbicides could be recommended for effective long-term weed control and for improving the productivity and profitability of cotton cultivation under HDPS. However, further studies on the implications of post-emergence herbicides on soil quality, especially the microbial activity, have to be carried out in the cotton-based cropping system to find out the residual effect on the soil, if any, and to harness the complete efficacy of the combination of herbicides.

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Authors' contributions

RN conceived the research idea, mentored the programme, and corrected and edited the manuscript. TSK carried out the research and prepared the draft manuscript. RN and SS supported the experimentation. RA, VD, KBS, NS, and PR mentored for data analysis and interpretation. SR and TR assisted in editing the article. All the authors have contributed to the final approval of the manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interest to declare.

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