PLANT SCIENCE TODAY
ISSN 2348-1900 (online)
Vol 11(sp4): 01–07
https://doi.org/10.14719/pst.5488

HORIZON
e-Publishing Group
HePG

RESEARCH ARTICLE

Optimizing cotton production through efficient weed management using herbicides: A promising solution for labour-scarce farming

T Sanjaykumar[1], R Nageswari[1]*, S Somasundaram[1], P Anantharaju[2], M Baskar[3], K Subrahmaniyan[1], K B Sujatha[4]*, R Anitha[4], V Dhanushkodi[3], A Renukadevi[3] & T Ramesh[1]

[1]Department of Agronomy, Tami Nadu Agricultural University, Coimbatore 641 003, India
[2]Department of Plant Breeding and Genetics, Tamil Nadu Agricultural University, Coimbatore 641 003, India
[3]Department of Soil Science and Agricultural Chemistry, Tamil Nadu Agricultural University, Coimbatore 641 003, India
[4]Department of Crop Physiology, Tamil Nadu Agricultural University, Coimbatore 641 003, India

*Email: nageswari.r@tnau.ac.in; kbsujathanair@gmail.com

OPEN ACCESS

ARTICLE HISTORY
Received: 29 September 2024
Accepted: 15 October 2024
Available online
Version 1.0 : 11 December 2024

Check for updates

Additional information

Peer review: Publisher thanks Sectional Editor and the other anonymous reviewers for their contribution to the peer review of this work.

Reprints & permissions information is available at https://horizonepublishing.com/journals/index.php/PST/open_access_policy

Publisher's Note: Horizon e-Publishing Group remains neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Indexing: Plant Science Today, published by Horizon e-Publishing Group, is covered by Scopus, Web of Science, BIOSIS Previews, Clarivate Analytics, NAAS, UGC Care, etc See https://horizonepublishing.com/journals/index.php/PST/indexing_abstracting

CITE THIS ARTICLE

Sanjaykumar T, Nageswari R, Somasundaram S, Anantharaju P, Baskar M, Subrahmaniyan K, Sujatha KB, Anitha R, Dhanushkodi V, Renukadevi A, Ramesh T . Optimizing cotton production through efficient weed management using herbicides: A promising solution for labour-scarce farming . Plant Science Today.2024;11(sp4):01-07. https://doi.org/10.14719/pst.5488

Abstract

Cotton, often referred to as 'White gold' and the 'King of fibre crops' holds a significant position as a cash and fibre crop in India. Weeds contribute to approximately 45 % of yield reduction in cotton cultivation at the national level, making weed management a critical factor in determining cotton productivity, particularly in high-density planting systems (HDPS). Effective weed control optimizes resource allocation, leading to improved growth parameters and higher yields. This study investigates the efficacy of various weed management practices, including pre-emergence and post-emergent herbicide applications, in enhancing the yield of cotton yield under HDPS. The results clearly demonstrate that a combination of PE Pendimethalin (1.0 kg a.i./ha), Metolachlor (1.0 kg a.i./ha), POE Pyrithiobac sodium (0.075 kg a.i./ha), and Quizalofop ethyl (0.075 kg a.i./ha) led to significantly greater plant height (113.4 cm) and dry matter production (7609 kg ha^{-1}). This treatment also resulted in significantly improved yield parameters, with a higher seed cotton yield of 2098 kg ha^{-1}, and yielded higher net returns of Rs.141961 ha^{-1} and a Benefit Cost Ratio (BCR) of 3.09. In the face of increasing labour scarcity, these herbicide-based weed management practices offer a viable solution for maximizing cotton productivity under HDPS. This approach supports the rapid expansion of cotton acreage in the current era of farm mechanization.

Keywords

cotton; economics; productivity; weed management

Introduction

Cotton (*Gossypium sp.*), often referred to as 'white gold' and the 'king of fiber crops', has long held a prominent position as both a cash and fiber crop in India. It is also called the 'Friendly Fiber' because it provides employment and generates foreign exchange. Cotton is cultivated in around 80 countries, thriving across a wide range of soil, climates, ecosystems, and production practices (1). Of the 53 *Gossypium* species found globally, India cultivates four: *Gossypium arboretum* and *Gossypium herbaceum* (collectively known as Asiatic cotton), *Gossypium hirsutum* (American Upland cotton), and *Gossypium barbadense* (Egyptian cotton). *G. hirsutum* is the most extensively cultivated, accounting for about 88% of hybrid cotton cultivated in India. Additionally, nearly all Bt cotton hybrids in the country belong to the *G.*

hirsutum variety, making up 90% of the total cotton cultivation (2, 3).

For the 2023-2024 cotton season, India had a cotton cultivation area of 126.80 lakh hectares, producing 325.22 lakh bales(1 bale= 170 kg), with an average productivity of approximately 436 kg per hectare. In Tamil Nadu, the cotton cultivation area is around 1.30 lakh hectares, yielding 2.78 lakh bales, with a productivity of 363.54 kg per hectare (4). Cotton fiber is a key raw material for the garment industry, providing income for about 6 million farmers in India and creating employment for 50 million people. It plays a vital role in the global economy, accounting for more than half of the total textile production. In addition to its fibre, cotton is a significant source of edible oil, which is rich in essential fatty acids, viz., linoleic, myristic, oleic, palmitic, palmitoleic, and stearic acids. A deficiency in these acids can lead to arterial constriction, reducing blood supply to the heart (5).

Biotic factors contributing to yield loss in cotton include weeds, pests such as bollworms, aphids, and whiteflies, as well as diseases like cotton wilt and root rot. These infestations and infections can severely impact cotton crop productivity. Among the primary causes of reduced cotton yields, weeds are the most significant, potentially reducing yields by 50–85% (6).

The critical period for weed control (CPWC) is the stage in the crop growth cycle when weed management is essential to prevent significant yield losses (7). For cotton, this period typically spans 30 to 60 days, aligning with the square and boll formation stages. Weed competition during this time has a considerable effect on cotton yield (8). To manage weeds, farmers employ various methods, including mechanical, biological, chemical, and allelopathic strategies (9). Due to labor shortages and rising labor costs, herbicidal weed control becomes crucial during the peak periods of weed infestation (10). Additionally, cotton hybrids are often grown with wider plant spacing and heavy fertilizer use, which invites infestation from multiple weed species (11).

Although several pre-emergent herbicides, such as pendimethalin and post-emergence herbicides, like Quizalofop ethyl, are available for weed control, the diverse weed flora in cotton requires the integrated use of both pre-and post-emergence herbicides. This combined approach is essential for effective weed management during the critical period of crop-weed competition (12).

Manual hand weeding is time-consuming as laborers must cover the entire field, and. farmers often struggle with labor shortages and rising wages. In many cases, the cost of herbicides is lower than the expenses associated with manual weeding. Therefore, the application of herbicides offers a more secure and economically viable approach to weed management. However, few studies have focused on the combined use of pre-and post-emergence herbicides, hand weeding, and power weeding in cotton, especially under the increasingly popular High Density Planting System (HDPS).

In light of this, the present study was initiated with the following objectives: to identify an effective weed management strategy for controlling weeds and enhancing the growth and yield of cotton under the HDPS.

Materials and Methods

The field experiment was conducted at the Cotton Research Station, Veppanthattai, located in the Veppanthattai block of Perambalur district, during the summer of 2024. The experimental site is situated 149 meters above sea level, at a latitude of 11° 32' N and longitude of 78° 83' E. The field consists of deep, calcareous, clayey soil that is moderately well-drained with slow permeability.

Experiment Details

The cotton variety VPT 2 was selected as the test crop and sown manually with a spacing of 90 x 15 cm, which is effective for HDPS. The field experiment consisted of ten treatments and three replications, following a Randomized Block Design (RBD).

The treatments were as follows:

T_1: PE Pendimethalin 1.0 kg a.i / ha + Hand weeding at 45th DAS.

T_2: PE Pendimethalin 1.0 kg a.i ha^{-1} + POE Pyrithiobac sodium 0.075 kg a.i ha^{-1} + Quizalofop ethyl 0.075 kg a.i ha^{-1}

T_3: PE Pendimethalin 1.0 kg a.i ha^{-1} + Power weeding at 45 DAS (),

T_4:PE Pendimethalin 1.0 kg a.i ha^{-1} + Metolachlor 1.0 kg a.i. ha^{-1} + hand weeding at 45 DAS (),

T_5: PE Pendimethalin 1.0 kg a.i ha^{-1} + Metolachlor 1.0 kg ha^{-1} + POE Pyrithrobac sodium 0.075 kg a.i ha^{-1} + Quizalofop ethyl 0.075 kg a.i ha^{-1}

T_6: PE Pendimethalin 1.0 kg a.i ha^{-1} + Metolachlor 1.0 kg a.i. ha^{-1} + Power weeding at 45 DAS

T_7: PE Pendimethalin 1.0 kg a.i ha^{-1} + Power weeding at 25 and 45 DAS

T_8: PE Pendimethalin 1.0 kg a.i ha^{-1} + Metolachlor 1.0 kg a.i. ha^{-1} + Power weeding at 25 and 45 DAS

T_9: with Weed free check, and

T_{10}: Unweeded control

Observation on plants

Plant height

The length of the main stem, measured from the cotyledonary node to the base of the last fully opened leaf, was recorded at the harvest stage from tagged plants. The average length was then expressed in cm.

Dry Matter Production (DMP)

Samples collected at the harvest stage were first shade-dried and then oven-dried at 80 °C until a constant weight was achieved. The DMP was recorded and expressed in kg/ha.

Leaf Area Index (LAI)

For calculating the Leaf Area Index (LAI), leaf length and maximum width of the third leaf from the top were measured from randomly tagged plants in each plot. The total number of leaves on each plant was also counted. Based

on observations taken at 30, 60, and 120 days after sowing (DAS), the Leaf Area Index (LAI) was calculated using the formula:(13).

$$LAI = [(L \times B \times K \times \text{Number of leaves plant}^{-1}) / \text{Area occupied by plant (cm}^2)]$$

Where, L = length of the leaf (cm), B = breadth of the leaf (cm), K = constant factor (0.73)

Observation on yield attributes and yield

Observation on yield attributes

During the harvest stage, various yield parameters such as number of bolls, boll weight, sympodial branches, and seed cotton yield were recorded.

Sympodial branches plant^{-1}

The number of sympodial branches per plant was counted from five randomly selected plants on the 120th day after sowing, and the average was expressed as the number of sympodial branches per plant.

Number of bolls per plant

The number of bolls was recorded from randomly tagged plants at 120 DAS and expressed as the number of bolls per plant.

Boll weight

The weight of fully opened and matured bolls, picked from tagged plants in each plot, was recorded. The mean boll weight was calculated and expressed in grams per boll (g boll^{-1}).

Observation on yield of cotton

Seed cotton yield

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

Stalk yield

After harvesting the bolls, the plants from the net plot were cut at ground level, sun-dried, and weighed. The stalk yield was calculated and expressed in kilograms per hectare (kg ha^{-1}).

Economic analysis

The costs accrued from sowing to harvest were calculated and expressed in rupees per hectare (Rs. ha^{-1}) and named Total Cost of Cultivation (TCC).

Gross return

Gross return was calculated based on the seed cotton yield and the prevailing market price, expressed in rupees per hectare (Rs. ha^{-1}).

Net return

Net return was determined by subtracting the total cost of cultivation from the gross return, following the detailed method outlined below, and presented in rupees per hectare (Rs. ha^{-1}).

Net return = Gross return minus cost of cultivation

Benefit-cost ratio

The benefit-cost ratio was determined by dividing the gross return by the total cost of cultivation.

B:C ratio = Gross return / Total cost of cultivation

Results and Discussion

Impact of different weed management practices on plant growth parameters in HDPS cotton at harvest stage

Plant height and Dry Matter Production (DMP)

The tallest plants, measuring 119.8 cm, and the highest dry matter production (DMP) of 8191 kg ha^{-1} were observed in the weed-free check (T_9). However, this result was statically comparable to the treatment involving PE application of Pendimethalin @ 1.0 kg a.i./ha + Metolachlor @ 1.0 kg /ha + POE Pyrithrobac sodium @ 0.075 kg a.i./ha + Quizalofop ethyl @ 0.075 kg a.i./ha (T_5), which recorded a plant height of 113.4 cm and DMP of 7609 kg ha^{-1}. The shortest plant height of 44.8 cm and the lowest DMP of 5400 kg ha^{-1} were recorded in the unweeded control (T_{10}), as presented in Table 1. The implementation of various weed management practices significantly enhanced cotton growth parameters, mainly due to effective weed control and higher weed control efficiency (WCE). This led to better

Table 1. Effect of weed management practices on plant height of cotton under HDPS.

	Treatment	Plant parameters (At harvest)		
		Plant height (cm)	DMP (Kg ha^{-1})	LAI
T1	PE Pendimethalin @ 1.0 kg a.i / ha + HW @ 45th DAS	78.9	5698	2.33
T2	PE Pendimethalin @ 1.0 kg a.i / ha + POE Pyrithiobac sodium 0.075 kg a.i/ha + Quizalofop ethyl @ 0.075 g a.i / ha	102.5	6799	2.96
T3	PE Pendimethalin @ 1.0 kg a.i / ha + PW @ 45 DAS	83.8	6475	2.61
T4	PE Pendimethalin @ 1.0 kg a.i / ha + Metolachlor @ 1.0 kg a.i./ha + HW @ 45 DAS	89.9	6723	2.75
T5	PE Pendimethalin @ 1.0 kg a.i / ha + Metolachlor @ 1.0 kg /ha + POE Pyrithrobac sodium @ 0.075 kg a.i / ha + Quizalofop ethyl @ 0.075 kg a.i / ha	113.4	7609	3.37
T6	PE Pendimethalin @ 1.0 kg a.i / ha + Metolachlor @ 1.0 kg a.i./ha + PW @ 45 DAS	93.8	6950	2.83
T7	PE Pendimethalin @ 1.0 kg a.i / ha + PW @ 25 & 45 DAS	97.3	6535	3.10
T8	PE Pendimethalin @ 1.0 kg a.i / ha + Metolachlor @ 1.0 kg a.i./ha + PW @ 25 & 45 DAS	106.0	7401	3.21
T9	Weed free check	119.8	8191	3.51
T10	Unweeded Control	44.8	5400	2.06
SEd		**3.4**	**342.6**	**0.06**
CD (P=0.05)		**7.2**	**719.9**	**0.13**

PE- pre emergence, **POE**- post emergence, **HW**- hand weeding, **PW**- power weeding, @- at the rate of.

foliage development and improved light interception for the crops, aligning with the findings of previous studies (14) conducted in the Southern Dry Zone of Karnataka.

Leaf Area Index (LAI)

The weed free check (T_9) recorded the higher LAI of 3.51, followed closely by the treatment with PE Pendimethalin @ 1.0 kg a.i./ha + Metolachlor @ 1.0 kg a.i./ha + POE Pyrithrobac sodium @ 0.075 kg a.i./ha + Quizalofop ethyl @ 0.075 kg a.i./ha (T_5), which achieved an LAI of 3.37. The higher LAI in these treatments were attributed to the efficient utilization of moisture, nutrients, and sunlight, as well as improved aeration in the root zone. These results are consistent with findings reported (15) in Bt cotton studies. The lowest LAI, 2.06 was observed in the unweeded control (T_{10}).

Impact of different weed management practices on yield parameters in HDPS cotton

Sympodial branches per plant

The weed-free check (T_9) recorded the highest number of sympodial branches per plant (22.23), which was comparable to the treatment with PE Pendimethalin @ 1.0 kg a.i./ha + Metolachlor @ 1.0 kg a.i./ha + POE Pyrithiobac sodium @ 0.075 kg a.i./ha + Quizalofop ethyl @ 0.075 kg a.i./ha (T_5), which recorded 20.92 branches. The lowest number of sympodial branches per plant (3.23) was observed in the unweeded control (T_{10}). Other studies reported similar findings (16).

Number of bolls per plant

Among the various weed management practices, the highest number of bolls per plant was recorded in the weed-free check (T_9) with 25.53 bolls, followed by the treatment with PE Pendimethalin @ 1.0 kg a.i./ha + Metolachlor @ 1.0 kg a.i./ha + POE Pyrithiobac sodium @ 0.075 kg a.i./ha + Quizalofop ethyl @ 0.075 kg a.i./ha (T_5), which recorded 22.40 bolls per plant. The lowest number of bolls per plant (4.97) was observed in the unweeded control (T_{10}). This result is consistent with findings from previous studies (17).

Boll weight

The heaviest bolls, weighing 5.41 g, were recorded in the weed-free check (T_9), which was comparable to the treatment of PE Pendimethalin @ 1.0 kg a.i./ha + Metolachlor @ 1.0 kg a.i./ha + POE Pyrithiobac sodium @ 0.075 kg a.i./ha + Quizalofop ethyl @ 0.075 kg a.i./ha (T_5), which had a weight of 5.37 g. In contrast, the unweeded control (T_{10}) recorded the lowest boll weight at 1.88 g, as presented in Table 2. This difference can be attributed to the application of pre-emergence herbicide followed by post-emergence herbicide, which likely resulted in lower weed density during the initial stage and further control of later germinating weeds. Similar findings regarding improved yield parameters through integrated weed management in cotton have been reported in previous studies (18, 19).

Table 2. Effect of weed management practices on yield parameters of cotton under HDPS.

	Treatment	Yield parameters		
		No. of sympodial branches plant^{-1}	No. of Bolls plant^{-1}	Boll weight (g)
T1	PE Pendimethalin @ 1.0 kg a.i / ha + HW @ 45th DAS	11.20	13.47	2.35
T2	PE Pendimethalin @ 1.0 kg a.i / ha + POE Pyrithiobac sodium 0.075 kg a.i/ha + Quizalofop ethyl @ 0.075 g a.i / ha	14.40	16.60	3.86
T3	PE Pendimethalin @ 1.0 kg a.i / ha + PW @ 45 DAS	16.78	15.40	2.87
T4	PE Pendimethalin @ 1.0 kg a.i / ha + Metolachlor @ 1.0 kg a.i./ha + HW @ 45 DAS	15.73	18.53	4.21
T5	PE Pendimethalin @ 1.0 kg a.i / ha + Metolachlor @ 1.0 kg /ha + POE Pyrithrobac sodium @ 0.075 kg a.i / ha + Quizalofop ethyl @ 0.075 kg a.i / ha	20.92	22.40	5.37
T6	PE Pendimethalin @ 1.0 kg a.i / ha + Metolachlor @ 1.0 kg a.i./ha + PW @ 45 DAS	16.97	19.53	4.59
T7	PE Pendimethalin @ 1.0 kg a.i / ha + PW @ 25 & 45 DAS	13.33	16.53	3.49
T8	PE Pendimethalin @ 1.0 kg a.i / ha + Metolachlor @ 1.0 kg a.i./ha + PW @ 25 & 45 DAS	18.19	20.80	4.78
T9	Weed free check	22.23	25.53	5.41
T10	Unweeded Control	3.23	4.97	1.88
SEd		**1.25**	**1.43**	**0.16**
CD (P=0.05)		**2.63**	**3.01**	**0.33**

PE- pre emergence, **POE**- post emergence, **HW**- hand weeding, **PW**- power weeding, @- at the rate of.

Impact of different weed management practices on yield of HDPS cotton

Seed cotton yield

The highest seed cotton yield of 2163 kg ha^{-1} was obtained from the weed-free check (T_9). This yield was statistically similar to that of the treatment involving PE Pendimethalin @ 1.0 kg a.i./ha + Metolachlor @ 1.0 kg a.i./ha + POE Pyrithiobac sodium @ 0.075 kg a.i./ha + Quizalofop ethyl @ 0.075 kg a.i./ha (T_5), which produced a yield of 2098 kg ha^{-1}. This outcome can be attributed to the effectiveness of pre-emergence (PE) applications of pendimethalin and metolachlor at 3 DAS, which effectively suppress the initial flush of weeds by inhibiting cell division through microtubule disruption and chlorophyll synthesis. This reduction in weed density decreases nutrient depletion and dry weight, ultimately enhancing crop growth and cotton yield (19). The subsequent flush of weed was controlled by the post-emergence (PoE) application of pyrithiobac sodium + quizalofop ethyl, further reducing competition from both grassy and broadleaf weeds. The sequential application of these herbicides during the critical growth period facilitated

better resource utilization and nutrient uptake, leading to improved seed cotton yield (20). In contrast, the unweeded control (T_{10}) yielded the lowest seed cotton output at 649 kg ha^{-1} (Table 3).

Table 3. Effect of weed management practices on yield of cotton under HDPS.

	Treatment	Yield	
		Seed cotton yield (Kg ha^{-1})	Stalk yield (Kg ha^{-1})
T1	PE Pendimethalin @ 1.0 kg a.i / ha + HW @ 45th DAS	1178	3197
T2	PE Pendimethalin @ 1.0 kg a.i / ha + POE Pyrithiobac sodium 0.075 kg a.i/ha + Quizalofop ethyl @ 0.075 g a.i / ha	1275	3401
T3	PE Pendimethalin @ 1.0 kg a.i / ha + PW @ 45 DAS	1368	3518
T4	PE Pendimethalin @ 1.0 kg a.i / ha + Metolachlor @ 1.0 kg a.i./ha + HW @ 45 DAS	1685	3249
T5	PE Pendimethalin @ 1.0 kg a.i / ha + Metolachlor @ 1.0 kg /ha + POE Pyrithrobac sodium @ 0.075 kg a.i / ha + Quizalofop ethyl @ 0.075 kg a.i / ha	2098	3989
T6	PE Pendimethalin @ 1.0 kg a.i / ha + Metolachlor @ 1.0 kg a.i./ha + PW @ 45 DAS	1819	3675
T7	PE Pendimethalin @ 1.0 kg a.i / ha + PW @ 25 & 45 DAS	1281	3798
T8	PE Pendimethalin @ 1.0 kg a.i / ha + Metolachlor @ 1.0 kg a.i./ha + PW @ 25 & 45 DAS	1954	3990
T9	Weed free check	2163	4239
T10	Unweeded Control	649	2962
SEd		**53.7**	**29.8**
CD (P=0.05)		**112.7**	**62.6**

PE- pre emergence, **POE**- post emergence, **HW**- hand weeding, **PW**- power weeding, @- at the rate of.

Stalk yield

Among the various weed management practices, the Weed Free Check (T_9) achieved a significantly higher stalk yield of 4239 kg ha-1, followed by the treatment of PE Pendimethalin @ 1.0 kg a.i./ha + Metolachlor @ 1.0 kg a.i./ha + PW @ 25 & 45 DAS (T_8) with a stalk yield of 3990 kg ha^{-1}. This success can be attributed to the effectiveness of PE pendimethalin and metolachlor applied at 3 DAS, which effectively prevented the initial flush of weeds by inhibiting cell division through microtubule disruption and chlorophyll synthesis. This resulted in reduced weed density, nutrient depletion, and dry weight, thereby enhancing crop growth and cotton yield (19). The second flush of weed was controlled by power weeding (PW) at 25 and 45 DAS, which further minimized competition from grassy and broadleaf weeds, allowing the crops better access to nutrients, water, and light. This reduction in weed interference created more favorable growth conditions, ultimately leading to a higher stalk yield. Similar results were reported by (21). In contrast, the unweeded control (T_{10}) recorded the lowest stalk yield at just 2962 kg ha^{-1}.

Impact of different weed management practices on the economics of HDPS cotton

Total cost of cultivation

Among the treatments, the highest cost of cultivation was recorded at Weedfree Check (T_9) amounting to Rs.94485 ha^{-1}. This was followed by the treatment of PE Pendimethalin @ 1.0 kg a.i./ha + Metolachlor @ 1.0 kg a.i./ha + PW @ 25 & 45 DAS (T_8, which incurred a cost of Rs.73109 ha^{-1}. In contrast, the unweeded control (T_{10}) had the lowest cost of cultivation, totalling Rs. 58485 ha^{-1}.

Net return (Rs. ha-1) and Benefit Cost Ratio (BCR)

Among the various weed treatments, the highest net return of Rs. 141961 ha^{-1} and benefit cost ratio (BCR) of 3.09 were recorded with the treatment of PE Pendimethalin @ 1.0 kg a.i./ha + Metolachlor @ 1.0 kg a.i./ha + POE Pyrithiobac sodium @ 0.075 kg a.i./ha + Quizalofop ethyl @ 0.075 kg a.i./ha (T5). This was followed by the treatment of PE Pendimethalin @ 1.0 kg a.i./ha + Metolachlor @ 1.0 kg a.i./ha + PW @ 25 & 45 DAS (T_8), which yielded a net return of Rs. 122291 ha^{-1} and a BCR of 2.67, as presented in Table 4. The increase in gross income, net income, and benefit-to-cost ratio observed under these treatments was attributed to the higher seed cotton yield, supporting the findings of previous studies (20). Conversely, the lowest

Table 4. Effect of weed management practices on economics of HDPS cotton.

	Treatment	Economics			
		Total cost of cultivation (Rs. ha^{-1})	Gross return (Rs. ha^{-1})	Net return (Rs. ha^{-1})	B:C ratio
T1	PE Pendimethalin @ 1.0 kg a.i / ha + HW @ 45th DAS	69249	117800	48551	1.70
T2	PE Pendimethalin @ 1.0 kg a.i / ha + POE Pyrithiobac sodium 0.075 kg a.i/ha + Quizalofop ethyl @ 0.075 g a.i / ha	66480	127500	61020	1.92
T3	PE Pendimethalin @ 1.0 kg a.i / ha + PW @ 45 DAS	67249	136800	69551	2.03
T4	PE Pendimethalin @ 1.0 kg a.i / ha + Metolachlor @ 1.0 kg a.i./ha + HW @ 45 DAS	70609	168500	97891	2.39
T5	PE Pendimethalin @ 1.0 kg a.i / ha + Metolachlor @ 1.0 kg /ha + POE Pyrithrobac sodium @ 0.075 kg a.i / ha + Quizalofop ethyl @ 0.075 kg a.i / ha	67839	209800	141961	3.09
T6	PE Pendimethalin @ 1.0 kg a.i / ha + Metolachlor @ 1.0 kg a.i./ha + PW @ 45 DAS	68609	181900	113291	2.65

T7	PE Pendimethalin @ 1.0 kg a.i / ha + PW @ 25 & 45 DAS	71749	128100	56351	1.79
T8	PE Pendimethalin @ 1.0 kg a.i / ha + Metolachlor @ 1.0 kg a.i./ha + PW @ 25 &	73109	195400	122291	2.67
T9	Weed free check	94485	216300	121815	2.29
T10	Unweeded Control	58485	69400	10915	1.19

PE- pre emergence, **POE**- post emergence, HW- hand weeding, **PW**- power weeding, @- at the rate of.

net return and BCR were recorded in unweeded control (T_{10}), with values of Rs. 10915 ha^{-1} and 1.19, respectively.

Conclusion

This study concluded that pre-emergence application of Pendimethalin @ 1.0 kg a.i./ha + Metolachlor @ 1.0 kg a.i./ha, followed by post-emergence application of Pyrithiobac sodium @ 0.075 kg a.i./ha + Quizalofop ethyl @ 0.075 kg a.i./ha, resulted in improved growth and yield parameters, seed cotton yield, and economic returns in cotton under a high-density planting system (HDPS). Therefore, the use of chemical weed management that integrates pre-emergence and post-emergence herbicides is recommended for effective long-term weed control and for enhancing the productivity and profitability of cotton cultivation under HDPS. However, further studies are needed to investigate the implications of post-emergence herbicides on soil quality, particularly concerning microbial activity.

Acknowledgements

The authors acknowledge the Tamil Nadu Agricultural University for the support rendered for conducting the research.

Authors' contributions

TS prepared the draft manuscript. RN conceived the research idea, mentored the research programme, and corrected and edited the manuscript. SS, KP, MB and KS supervised and supported the experimentation. KBS and RA mentored for data interpretation. VD, AR and TR assisted in editing the manuscript. All authors read and approved the final manuscript.

Compliance with ethical standards

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

Ethical issues: None

References

1. Raut SA, Meshram JH, Lal EP. Effect of mepiquat chloride on cotton var Suraj shoot and root growth behaviour. International Journal of Chemical Studies. 2019;7(3):946.
2. Doğan MN, Jabran K, Unay A. Integrated weed management in cotton. In: Chauhan BS, Mahajan G, editors. Recent Advances in Weed Management [Internet]. New York, NY: Springer New York; 2014 [cited 2024 Feb 26]. p. 197-222. https://doi.org/10.1007/978-1-4939-1019-9_9
3. Kumar M, Premalatha N, Mahalingam L, Sakthivel N, Senguttuvan K, Latha P. High density planting system of cotton in India: Status and breeding strategies. In: Plant Breeding-Current and Future Views. IntechOpen; 2020. https://doi.org/10.5772/intechopen.94905
4. Ministry of textiles India. Cotton Report. 2024. Available from: https://www.texmin.nic.in/sites/default/files/Cotton%20Production%20and%20consumption%20in%20Major%20countries-1.pdf
5. Arunvenkatesh S, Rajendran K. Evaluation of plant density and cotton genotypes (*Gossypium hirsutum* L.) on cotton yield and fibre quality. International Journal of Forestry and Crop Improvement. 2013;40(1):1-5.
6. Venugopalan M, Kranthi K, Blaise D, Lakde S, Sankaranarayana K. High density planting system in cotton- The Brazil experience and Indian initiatives. CoRJ. 2013;5(2):172-85
7. Doğan MN, Ünay A, Boz Ö, Albay F. Determination of optimum weed control timing in maize (*Zea mays* L.). Turk J Agric For. 2004;28(5):349-54.
8. Ahmad S, Hasanuzzaman M. Cotton production and uses. Agronomy, Crop Protection and Postharvest Technologies. Springer Nature Singapore Pte Ltd. 2020. https://doi.org/10.1007/978-981-15-1472-2
9. Hakoomat A, Arooj M, Sarwar N, Areeb A, Shahzad AN, Hussain S. Application of pre and post emergence herbicide under improved field irrigation system proved a sustainable weed management strategy in cotton crop. Planta Daninha [Internet]. 2017 Sep 4 [cited 2024 Feb 26];35(0). https://doi.org/10.1590/s0100-83582017350100052
10. Dharani M, Rathika S, Avudaithai S, Baskar M, Meena S, Ramesh T. Effect of herbigation on weed control and yield of drip irrigated cotton. International Journal of Plant and Soil Science. 2023;8;35(21):1003-10. https://doi.org/10.9734/ijpss/2023/v35i214071
11. Nalini K, Muthukrishnan P, Chinnusamy C. Evaluation of pendimethalin 38.7 EC on weed management in winter irrigated cotton. Madras Agricultural Journal. 2011;98(1):165-68. https://doi.org/10.29321/MAJ.10.100267
12. Madavi B. Effect of high density planting and weed management practices on weed dry matter, weed indices and yield of Bt cotton. International Journal of Pure Applied Bioscience. 2017;30;5(4):1945-50. https://doi.org/10.18782/2320-7051.5273
13. Ashley D, Doss B, Bennett O. A method of determining leaf area in cotton. Agronomy Journal. 1963;55(6):584-85. https://doi.org/10.2134/agronj1963.00021962005500060027x
14. Honnappa H, Shekara B. Seed cotton yield and economics of hybrid cotton (*Gossypium* spp.) as influenced by weed management practices in Southern dry zone of Karnataka. Mysore Journal of Agricultural Science. 2018;52(3):511-18.
15. Pandagale A, Baig K, Rathod S, Kadam G, Namade T. Effect of various weedicides on weed control, yield and economics in Bt cotton (*Gossypium hirsutum* L.). IJOTA. 2018;36(4):1091-101.
16. Mathukia R, Sagarka B, Mathukia P, Savaliya N. Efficiency of some herbicides and manual weeding for weed control in irrigated Bt cotton. Indian Journal of Agricultural Research. 2018;52(3):315-18. https://doi.org/10.18805/IJARe.A-4963

17. Rathod N, Khargakharate V, Deshmane A, Bhosale B. Impact of pre and post emergence of herbicides on growth, weed indices and yield attributes of Bt cotton hybrids under high density planting in Maharashtra region. The Pharma Innovation Journal. 2023;12(2):651-55.

18. Malarkodi N, Balasubramanian R. Integrated weed management practices with botanicals on weed control in cotton. Journal of Innovative Agriculture. 2017;4(4):29-43.

19. Panchal P, Patel V, Chaudhari D, Dohat M. Evaluation of different herbicides on growth, yield attributes and yield of Bt cotton and their residual effect on succeeding summer groundnut. The Pharma Innovation Journal. 2022;11(12):2121-424.

20. Veeraputhiran R. Integrated weed management in irrigated cotton under high density planting system. Indian Journal of Weed Science. 2023;55(1):42-45. https://doi.org/10.5958/0974-8164.2023.00007.2

21. Verma V, Tewari A, Dhemri S. Effect of atrazine on weed management in winter maize-green gram cropping system in central plain zone of Uttar Pradesh. Indian Journal of Weed Science. 2009;41(1 & 2):41-45.