

IMPACT OF INTEGRATED WEED MANAGEMENT ON FLAT-SOWN COTTON (*GOSSYPIUM HIRSUTUM* L.)

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ABSTRACT

Field experiments were conducted during 2006 and 2007 to develop an effective integrated method of weed control for conventional flat-sown cotton. Treatments included combinations of chemical (No chemical, Pendimethalin @2.5 L ha⁻¹, and Glyphosate @4.7 L ha⁻¹) and mechanical (No inter-culturing, Inter-culturing, Hand-weeding, and Inter-culturing + Hand-weeding) methods of weed control. A RCBD experiment with split plot arrangements was laid out; where chemical treatments were kept in main plots while mechanical treatments in subplots. Pendimethalin in combination with different mechanical treatments produced the maximum weed control (97%) at 30 DAS (days after sowing), while at 60 DAS the maximum weed control (91%) was achieved by application of Glyphosate in combination with Inter-culturing + hand-weeding. Highest seed cotton yields 2578 and 3613 kg ha⁻¹ were recorded with application of Pendimethalin in combination with Inter-culturing + hand-weeding, followed by 2468 and 3396 kg ha⁻¹ with application of Pendimethalin in combination with Hand-weeding during 2006 and 2007, respectively. Application of Pendimethalin in combination with Inter-culturing and hand-weeding produced the maximum plant dry weight (kg ha⁻¹). Variations in characteristics of fiber quality i.e. %GOT, staple length (mm), and micronaire (µg inch⁻¹) in response to different treatment combinations were either non significant or significant with very little practical importance. It is suggested that pre-emergence application of Pendimethalin in combination with Inter-culturing + hand-weeding may be used for efficient weed control and higher yields in flat-sown cotton.

Key words: Weed control, cotton, herbicide, flat sowing, hand-weeding, inter-culturing, integrated weed management.

INTRODUCTION

Cotton (*Gossypium hirsutum* L.) is an important cash crop of Pakistan that contributes about 6.9% of the value added in agriculture and about 1.4% to GDP and 60% to the foreign exchange earning of the country (Anonymous, 2011). The country ranks fourth, third, and fourth in total production, export, and consumption of cotton in the world. In the country, cotton is grown on an area of 2689 thousand hectares with an annual production of 11460 thousand bales and having an average seed cotton yield of 725 kg ha⁻¹ (Anonymous, 2011). Despite higher yield potential, average seed cotton yield in the country are much lower than major cotton growing countries. Only alternative to cope with the present situation is to enhance cotton yields by intensive agriculture farming system from the existing cultivated area and by adapting advanced farming techniques and alternative protection measures against weed infestations.

Heavy weed infestations due to poor weed management practices are estimated to reduce cotton seed yields by about 30-40%. Chemical weed control in cotton has been successfully utilized in the recent past. It has not only decreased the labor costs but at the same time also increased the crop yields. However, continuous use of similar herbicides or sometimes the wrong use of

herbicides in cotton-wheat cropping pattern has induced resistance in weeds against these herbicides. A number of weed biotypes with herbicide resistance have been reported for more than twenty types of herbicides (Heap, 2010). Glyphosate is widely used post-emergence herbicide for weed management in cotton crop production. However numerous studies have indicated the prevalence of Glyphosate resistance in weed populations on a large scale in maize, cotton and soybean genetically engineered herbicide tolerant systems (Johnson *et al.*, 2009; Owen, 2011). This has increased the cost of production in terms of herbicide wastage and yield losses due to ineffective weed control. High input cost of production always remains a major problem for farmers around the world. In order to maximize crop profits, researchers have introduced an alternative cultivation system against the conventional system such as the use of pre- and post-emergence herbicides along with mechanical weed control methods, integrated for efficient weed control (Darawshah *et al.*, 2009).

It is therefore necessary to develop an integrated weed management system that can reduce the use of herbicides without impacting crop yields. Integrated weed management is the use of different weed control practices in combination for effective weed suppression. These agronomic practices include crop rotation, mechanical and cultural weed control and use of diverse

herbicides. Use of integrated weed management practices has been successful in controlling weed infestations in various crops. Aim of the present study was to devise an effective integrated weed control method suitable for conventional flat-planted cotton crop. In this study, both Pendimethalin (pre-emergence) and Glyphosate (post-emergence) were used to investigate their effects on seed cotton yield and its components under different planting methods. Mechanical methods i.e. inter-culturing and hand-weeding were included to control the weeds as part of the integrated weed management strategy.

MATERIALS AND METHODS

Two field experiments were conducted during the 2006 and 2007 crop years at Central Cotton Research Institute (CCRI), Multan, Pakistan (30° 12' N, 71° 28' E, 123m elevation above mean sea level). The experiments during 2006 and 2007 were conducted at the same experimental site. Climatic conditions during the crop years are given in Figure 2. The experimental year 2006 received only 59 mm total rainfall (Fig. 2) during the crop season (May-Dec.). In comparison, the crop season in 2007 was relatively wet particularly during the peak vegetative growth period (July-Sep.). Total amount of rainfall received during crop season 2007 was 153 mm. To diagnose the fertility status of the experimental site, two composite soil samples collected from two depth ranges i.e. 0-15 cm and 15-30 cm were analyzed using the method of Ryan *et al.* (2001). It was a silt loam soil with < 1% (0.83-0.87) organic matter, EC_e varied from 2.61 to 2.77 dSm^{-1} . Moreover, experimental soil was deficient in major nutrients especially N and P. Experiments were laid out in randomized complete block design with split plot arrangements, keeping chemical treatments in main plot and mechanical treatments in subplots. Weed control treatments included three chemical i.e., No chemical applied, Pendimethalin 330E @ 2.5 L ha⁻¹, pre-emergence, and Glyphosate 490 G/L @ 4.7 L ha⁻¹, post-emergence and four mechanical, No inter-culturing, Inter-culturing alone, Hand-weeding alone, and Inter-culturing + hand-weeding. Each experiment consisted of four replications with a net plot size of 3 m x 9 m, with row to row distance of 75 cm and plant to plant spacing of 30cm. Seed bed was properly prepared (conventional method) and after laying out the experimental area, pre-emergence treatments (Pendimethalin (Stomp 330 E) @ 2.5 L/ha) was sprayed with a knap sack hand sprayer on the same day before sowing. Cotton seeds of cv. CIM-496 25 kg ha⁻¹ were planted on 25 May, 2006 and 21 May, 2007 during both years by a cotton planter at 75 cm row spacing while plant to plant distance was maintained at 30 cm at thinning time. The post-emergence herbicide i.e., Glyphosate (Roundup 490 G/L) @ 4.7 L/ha was sprayed by knap sack hand sprayer 35 days after sowing during

both years. The post emergence herbicide (Glyphosate @ 4.7 L ha⁻¹) was applied with shield nozzle to protect the crop. This shield touches the ground and directs the spray only to weeds thus protecting the crop plants from herbicide injury. One dry inter-culturing (25 days after sowing, DAS) and two post irrigation inter-culturings were done by a tractor-driven implement at 36 and 48 DAS. Two hand-weedings (eradication of weeds with special hand tool, kesola), one under dry conditions and the second one after first irrigation were practiced at 25 and 42 DAS, respectively. Six irrigations in total were applied during each crop season. All the fertilizers, 60 kg P₂O₅ ha⁻¹ at the time of seed bed preparation and 150 kg N ha⁻¹ in three split doses i.e. 1/3 nitrogen at sowing, 1/3 at bud formation (3rd week of July) and 1/3 at peak flowering (3rd week of August) stage were applied to all the plots in both seasons. All other agronomic practices and plant protection measures were done as per need of the crop.

Dry biomass of broad and narrow leaf weeds were determined separately by randomly selecting two sites from each plot with the help of 2500 cm² quadrilateral and then converted into m². For dry biomass (g m⁻²), weed samples were dried in an oven at 70°C to a constant temperature and weighed. To measure total plant dry weight, four crop plants per treatment free of mechanical injury or obvious faults were individually selected. The total material was dried in an oven at 70°C to a constant temperature, weighed, and estimated on per unit land area basis. Data on seed cotton yield were recorded at the time of crop harvest by taking the yield of each plot and then converted into kg ha⁻¹. To calculate ginning out turn (%GOT), 100 g sample of seed cotton was air-dried and ginned with ginner. Physical characteristics of cotton fibre viz staple length and micronaire were determined as described by ASTM Standard (1997). Data recorded were subjected to ANOVA using the ``MSTAT`` statistical program for RCBD with split-split plot arrangements and tested for year by treatment interactions. The treatment means were compared using LSD test at 5% probability when the F-values were significant.

RESULTS AND DISCUSSION

Data analysis showed that year by treatment interactions for different variables were significant. Therefore, data for 2006 and 2007 were analyzed separately and presented as individual experiments.

Weed Dry Biomass (g m⁻²) at 30 DAS: Weeds in No-chemical and No-inter-culturing plots utilized the environmental resources for a longer period of time and ultimately produced more weed dry mass than plots where weeds were controlled by different chemical and mechanical methods. Results showed that different

chemical and mechanical treatments significantly reduced the weed dry biomass of both broad and narrow leaf weeds at 30 DAS in flat-sown cotton (Table 1). At this stage weed infestation was mainly dominated by broad leaf weeds. Among chemical treatments, Pendimethalin application resulted in the lowest weed dry mass (by 97%) during both years. These results are in accordance with that of Chaudhary *et al.* (2011) who observed an effective weed control with pre-emergence application of Pendimethalin. As Glyphosate was not applied to the respective plots at this stage (30 DAS), the weed dry mass was not significantly different between Glyphosate and No-chemical treatments. Among mechanical treatments, Inter-culturing + hand-weeding reduced the maximum dry mass of both broad and narrow leaf weeds. Interactions between chemical and mechanical weed control treatments showed that Pendimethalin in combination with different mechanical treatments significantly reduced the weed dry mass at 30 DAS in flat planted cotton.

Weed Dry Biomass (g m^{-2}) at 60 DAS: Among various chemical treatments, Glyphosate significantly reduced the dry biomass of both broad and narrow leaf weeds over Pendimethalin and no-chemical treatments during both years (2006 and 2007) (Table 2). Similarly, Pendimethalin treatment significantly reduced the weed dry weight as compared to no chemical treatment. The average total dry weights of weeds recorded during 2006 were 60.7, 123.3 and 266.1 g m^{-2} in Glyphosate, Pendimethalin and no-chemical treatments, respectively. Equivalent values during 2007 were 40.0, 80.8 and 152.0 g m^{-2} , respectively. The lower weed infestation during 2007 could be attributed to the residual effects of weed management during the previous year, as both experiments were conducted at the same site. Weed control by various treatments during 2006 would have prevented the weeds to set seeds and thus reduced the weed pressure in the following year. Among mechanical treatments, Inter-culturing + Hand-weeding treatment gave the lowest total dry weight of weeds than all other treatments during both seasons (Table 1).

The interaction between chemical and mechanical treatments showed that application of Glyphosate along with Inter-culturing + hand-weeding significantly reduced the total weed dry biomass (43.3 g m^{-2} , 26.0 g m^{-2} during 2006 and 2007, respectively). It is obvious from results (Fig. 1) that the sole application of Pendimethalin (no inter-culturing) was not effective and gave weed control of only 48%. At 60 DAS, lower weed control by Pendimethalin was due to lower mortality of narrow leaf weeds (Fig. 1). This observation is supported by findings of Maqbool *et al.* (2001) and Khan & Khan (2003) who observed that Pendimethalin did not effectively control narrow leaf weeds particularly *cyprus rotundus*. In comparison, post-emergence application of

glyphosate at 35 DAS reduced the weed biomass of both broad and narrow leaf weeds and gave a total weed control of 78% at 60 DAS. Koger *et al.* (2005) reported that glyphosate effectively controls both narrow and broad leaf weeds when applied at early, mid or post emergence.

Both weedicides gave significantly higher weed control when applied in combination with different mechanical practices. At 60 DAS, Glyphosate in combination with Inter-culturing + hand-weeding gave the maximum weed control of 91% over untreated control. Whereas, no inter-culturing and/ no chemical treatment combinations gave significantly maximum dry weight of weeds. Earlier researchers also reported similar results where maximum weed control in cotton was achieved by herbicide application + manual weeding or inter-culturing (Deshpande *et al.*, 2006; Sheikh *et al.*, 2006; Oad *et al.*, 2007). The integrated weed management system has proved to be more effective for conventional flat-sowing of cotton; therefore farmers must not depend on any one method of weed control.

Biological Yield (kg ha^{-1}): Table 3 presents the effects of treatments on total plant dry biomass at final harvest. During both years, Pendimethalin application resulted in maximum total dry weight as compared to Glyphosate and no-chemical treatments. In comparison to no-chemical treatment, Glyphosate application also increased the biological yield. Different mechanical treatments also showed significant differences in total dry weight at final harvest. The treatment Inter-culturing + hand-weeding produced the maximum biological yield as compared to other mechanical treatments during both years. Differences for total plant dry weight between Inter-culturing and Hand-weeding alone treatments were not significant during both years. As for as the interaction is concerned, application of Pendimethalin along with Inter-culturing + hand-weeding showed the maximum plant dry weight of 9370 kg ha^{-1} in 2006 and 11282 kg ha^{-1} in 2007 as compared to other treatment combinations. Significantly higher biological yields in 2007 than previous year could be associated to a relatively higher amount of rainfall received during the crop season, particularly during peak vegetative growth period. Moreover, lower weed pressure in 2007 (as evident from data, Table 1 & 2) due to weed control by various treatments in previous year, would also have contributed to higher yields in 2007.

Seed Cotton Yield (kg ha^{-1}): Results showed that seed cotton yield increased significantly with Pendimethalin treatment over Glyphosate and no-chemical treatments during both years (Table 3). The maximum seed cotton yield was obtained with Pendimethalin treatment (2280 and 3172 kg ha^{-1} during 2006 and 2007, respectively) followed by Glyphosate and no-chemical treatments. Higher yields during 2007 seem to be the result of better

climatic conditions and lower weed infestation during crop cycle in 2007 than the previous year. Among mechanical treatments, the highest seed cotton yield was obtained with Inter-culturing + hand-weeding treatment during both years. The interactions between different chemical and mechanical treatments regarding seed cotton yield were significant during both years. Maximum seed cotton yield was obtained by Pendimethalin x Inter-culturing + hand-weeding treatment combination (2578 and 3613 kg ha⁻¹ during 2006 and 2007, respectively) as compared to other treatment combinations. The highest seed cotton yields observed in this study are comparable to the maximum yields of 2671 kg ha⁻¹ to 3943 kg ha⁻¹ reported by other researchers (Ali *et al.*, 2005; Sheikh *et al.*, 2006; Oad *et al.*, 2007; Muhammad *et al.*, 2009). These results substantiate the findings of others who also stated that herbicide alone or in combination with hand hoeing gave more seed cotton yield than control treatment (Tanveer *et al.*, 2003; Grey *et al.*, 2008). Higher yields produced by the treatment Pendimethalin x Inter-culturing + hand-weeding could be associated to a better weed control during critical period of weed control (CPWC; from emergence till last sampling at 60 DAS). CPWC is a

period during which weeds must be controlled to avoid yield reductions (Cardoso *et al.*, 2011). The CPWC measured for cotton varies from 8-66 days after emergence (Salgado *et al.*, 2002) to 31-74 days after emergence, depending on planting date, climatic conditions and cultivar (Cardoso *et al.*, 2011). The lowest seed cotton yields of 965 and 1339 kg ha⁻¹ during 2006 and 2007, respectively were found in treatment combination of No-chemical x no-inter-culturing.

Fiber Characteristics: The data on ginning out turn percentage (GOT%; Table 4) showed that Pendimethalin treatment significantly increased the GOT percentage as compared to No-chemical treatment. Differences between Pendimethalin and Glyphosate for GOT were not significant during both years. Among mechanical treatments, Inter-culturing + hand-weeding showed the maximum GOT percentage. Differences in GOT% between Hand weeding and Inter-culturing + hand-weeding were not significant. The interaction between treatments showed that the weeding combination of Inter-culturing + hand-weeding produced the maximum GOT percentage.

Table 1. Weed dry biomass (gm⁻²) at 30 DAS as affected by different integrated chemical and mechanical weed management practices in flat sown cotton

Treatments	2006			2007		
	Broad Leaf	Narrow Leaf	Total	Broad Leaf	Narrow Leaf	Total
Chemical (C)						
C1=No Chemical	34.3a	2.8a	37.1a	27.1a	3.4a	30.5a
C2=Pendimethalin	1.9b	0.5b	2.4b	1.7b	0.3b	2.0b
C3=Glyphosate	34.6a	2.9a	37.4a	26.5a	3.4a	29.9a
LSD at 5%	1.54	0.13	1.58	1.54	0.06	1.57
Mechanical (M)						
M1=No Inter-culturing	46.3a	4.2a	50.5a	38.1a	4.7a	42.8a
M2=Inter-culturing	20.5b	1.7b	22.2b	16.0b	2.0b	18.0b
M3=Hand weeding	16.1c	1.2c	17.3c	11.2c	1.5c	12.7c
M4=Inter-culturing + Hand Weeding	11.5d	1.0d	12.6d	8.4d	1.3d	9.7d
LSD at 5%	1.78	0.15	1.83	1.78	0.07	1.81
Interaction between C × M						
C1 × M1	67.5	5.8	73.3	56.5	6.7	63.2
C1 × M2	29.5	2.2	31.7	22.9	2.9	25.8
C1 × M3	22.6	1.8	24.4	16.5	2.1	18.6
C1 × M4	17.7	1.5	19.1	12.5	1.9	14.4
C2 × M1	2.5	0.5	3.0	2.0	0.5	2.5
C2 × M2	2.0	0.5	2.4	1.7	0.3	1.9
C2 × M3	1.8	0.5	2.2	1.6	0.2	1.8
C2 × M4	1.6	0.4	2.0	1.6	0.2	1.7
C3 × M1	69.0	6.3	75.2	55.8	6.9	62.6
C3 × M2	30.1	2.4	32.5	23.6	2.8	26.3
C3 × M3	23.9	1.5	25.4	15.4	2.3	17.7
C3 × M4	15.3	1.3	16.6	11.3	1.8	13.0
LSD at 5%	3.08	0.26	3.17	3.09	0.12	3.14

Table 2. Weed dry biomass (gm^{-2}) at 60 DAS as affected by different integrated chemical and mechanical weed management practices in flat sown cotton

Treatments	2006			2007		
	Broad Leaf	Narrow Leaf	Total	Broad Leaf	Narrow Leaf	Total
Chemical (C)						
C1=No Chemical	141.3a	124.8a	266.1a	77.7a	74.3a	152.0a
C2=Pendimethalin	55.3b	68.0b	123.3b	36.8b	44.0b	80.8b
C3=Glyphosate	35.7c	24.9c	60.7c	25.1c	14.9c	40.0c
LSD at 5%	6.23	3.93	6.74	1.56	1.12	1.83
Mechanical (M)						
M1=No Inter-culturing	104.6a	153.0a	257.5a	88.0a	93.4a	181.4a
M2=Inter-culturing	86.4b	50.1b	136.5b	42.4b	40.2b	82.6b
M3=Hand weeding	67.4c	45.6bc	113.0c	30.8c	26.2c	56.9c
M4=Inter-culturing + Hand Weeding	51.5d	41.6c	93.1d	24.9d	17.8d	42.7d
LSD at 5%	7.19	4.54	7.78	1.80	1.29	2.11
Interaction between C × M						
C1 × M1	197.5	232.7	430.2	176.7	147.5	324.2
C1 × M2	163.8	98.0	261.8	65.5	72.5	138.0
C1 × M3	120.9	87.5	208.4	40.0	45.5	85.5
C1 × M4	83.3	80.8	164.1	28.5	31.7	60.2
C2 × M1	67.2	175.9	243.1	52.2	102.5	154.7
C2 × M2	60.7	34.1	94.7	36.6	35.5	72.1
C2 × M3	50.7	32.8	83.6	30.8	23.5	54.3
C2 × M4	42.6	29.3	71.9	27.5	14.5	42.0
C3 × M1	49.0	50.3	99.3	35.1	30.2	65.3
C3 × M2	34.8	18.3	53.1	25.2	12.5	37.7
C3 × M3	30.5	16.5	47.0	21.5	9.5	31.0
C3 × M4	28.6	14.7	43.3	18.7	7.3	26.0
LSD at 5%	12.45	7.86	13.48	3.12	2.23	3.66

Data showed that the staple length (mm) was not affected by chemical treatments in both years (Table 4). The average staple length among different chemical treatments varied from 27.9 to 28.2 mm and from 29.0 to 29.3 mm, in 2006 and 2007, respectively. Different mechanical weed control practices however significantly affected the staple length in either year. Both Hand-weeding and Inter-culturing + hand-weeding treatments showed an increase in staple length as compared to Inter-culturing and No-inter-culturing treatments. Interactions between chemical x mechanical weed control treatments regarding staple length were not significant during both years. Data showed no significant differences in micronaire values ($\mu\text{g inch}^{-1}$) among different chemical and mechanical treatments during both years (Table 4).

Similarly interactions between different chemical x mechanical treatments were also not significant during both years.

The changes in fiber properties observed in the present study were too small to be of any practical importance. Blaise, 2006 did indicate inconsistent trends with regard to effects of chemical and cultural systems on fiber quality. Importantly, the present study indicates that both chemical and mechanical weed control techniques do not adversely affect fiber quality. Holloway *et al.* (2008) also confirmed that no adverse effects on yield or fiber quality parameters of cotton were recorded following multiple applications of full rates of several formulations of Glyphosate and Glufosinate ammonium herbicides, alone or in mixtures.

Table 3. Effect of different integrated chemical and mechanical weed management practices on biological and seed cotton yield of flat sown cotton.

Treatments	Biological Yield (kg ha^{-1})		Seed Cotton Yield (kg ha^{-1})	
	2006	2007	2006	2007
Chemical (C)				
C1=No Chemical	7667c	8885c	1614c	2285c
C2=Pendimethalin	8783a	10675a	2280a	3172a
C3=Glyphosate	8520b	9495b	2066b	2640b

LSD at 5%	150.80	183.40	149.60	155.10
Mechanical (M)				
M1=No Inter-culturing	6647d	8058c	1381c	1976c
M2=Inter-culturing	8850b	10096b	2018b	2723b
M3=Hand weeding	8758c	10055b	2199ab	2895b
M4=Inter-culturing + Hand Weeding	9038a	10531a	2349a	3202a
LSD at 5%	183.70	211.80	172.80	179.10
Interaction between C × M				
C1 × M1	5672	6702	965	1339
C1 × M2	8231	9435	1607	2358
C1 × M3	8134	9376	1852	2536
C1 × M4	8632	10026	2030	2906
C2 × M1	7298	8929	1716	2411
C2 × M2	9245	11266	2359	3268
C2 × M3	9217	11224	2468	3396
C2 × M4	9370	11282	2578	3613
C3 × M1	6970	8541	1462	2177
C3 × M2	9073	9586	2087	2542
C3 × M3	8924	9566	2277	2752
C3 × M4	9112	10286	2439	3087
LSD at 5%	318.30	366.80	299.30	310.20

Table 4. Effect of different integrated chemical and mechanical weed management practices on Ginning out turn, Staple length and Micronaire values of flat-sown cotton.

Treatments	Ginning out turn (%)		Staple length (mm)		Micronaire ($\mu\text{g inch}^{-1}$)	
	2006	2007	2006	2007	2006	2007
Chemical (C)						
C1=No Chemical	40.4b	41.0b	27.9	28.9	5.0	4.7
C2=Pendimethalin	41.0a	41.8a	28.2	29.3	4.9	4.6
C3=Glyphosate	40.7ab	41.3b	28.1	29.1	4.9	4.7
LSD at 5%	0.51	0.49	ns	ns	ns	ns
Mechanical (M)						
M1=No Inter-culturing	40.2c	40.7c	27.8b	28.9b	5.0	4.8
M2=Inter-culturing	40.5bc	41.2bc	27.9ab	28.9b	4.9	4.7
M3=Hand weeding	40.8ab	41.5ab	28.1ab	29.1ab	4.9	4.6
M4=Inter-culturing + Hand Weeding	41.2a	42.0a	28.4a	29.2a	4.8	4.6
LSD at 5%	0.59	0.57	0.50	0.35	ns	ns
Interaction between C × M						
C1 × M1	40.1	40.2	27.6	28.8	5.1	4.9
C1 × M2	40.3	40.8	27.8	28.9	5.0	4.8
C1 × M3	40.5	41.4	28.1	29.0	5.0	4.7
C1 × M4	40.6	41.6	28.2	29.1	4.9	4.6
C2 × M1	40.4	41.3	27.9	28.9	4.9	4.8
C2 × M2	40.7	41.5	28.0	29.0	4.9	4.7
C2 × M3	41.1	41.8	28.2	29.2	4.8	4.6
C2 × M4	41.8	42.6	28.6	29.4	4.8	4.5
C3 × M1	40.2	40.8	27.9	28.9	5.0	4.8
C3 × M2	40.6	41.3	27.9	28.9	5.0	4.7
C3 × M3	40.8	41.4	28.2	29.2	4.9	4.7
C3 × M4	41.4	41.8	28.3	29.3	4.9	4.6
LSD at 5%	1.02	0.98	ns	ns	ns	Ns

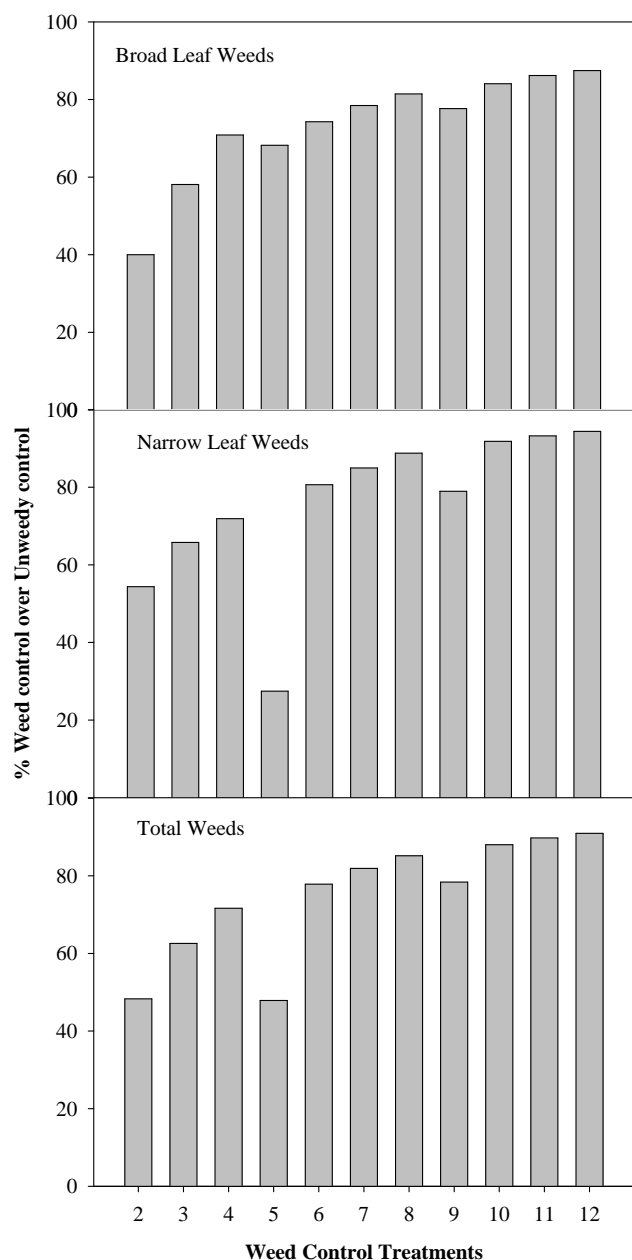


Fig. 1. % weed control at 60 DAS (two years average) by different integrated chemical and mechanical weed management practices over un-weedy control.

Un-weedy control: No Chemical + No Inter-culturing, 2: No Chemical + Inter-culturing, 3: No Chemical + Hand weeding, 4: No Chemical + Inter-culturing + Hand weeding, 5: Pendimethalin + No Inter-culturing, 6: Pendimethalin + Inter-culturing, 7: Pendimethalin + Hand weeding, 8: Pendimethalin + Inter-culturing + Hand weeding, 9: Glyphosate + No Inter-culturing, 10: Glyphosate + Inter-culturing, 11: Glyphosate + Hand weeding, 12: Glyphosate + Inter-culturing + Hand weeding.

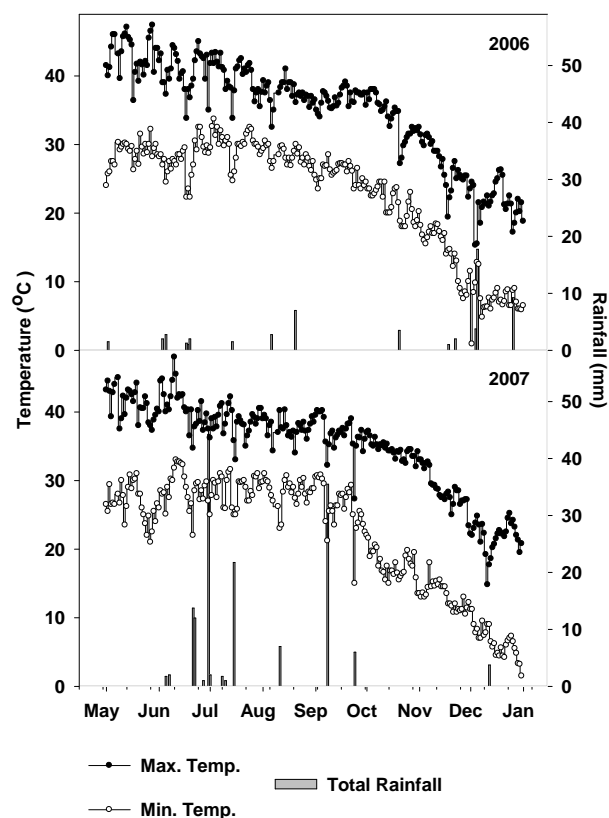


Fig. 2. Mean daily temperatures and mean daily rainfall (mm) during crop seasons of 2006 and 2007.

Conclusions: This study showed that the integrated use of Glyphosate and Pendimethaline in combination with inter-culturing and hand-weeding efficiently controlled the weeds as compared to use of herbicides or mechanical methods alone in flat-sown cotton. Pre-emergence application of Pendimethaline in combination with inter-culturing and hand-weeding achieved the highest weed control (>91%) which resulted in highest seed-cotton yield.

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