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Sequential application of herbicides for control of weeds in rainfed Bt cotton

D. Lakshmi Kalyani*, A. Sita Rama Sarma and Y. Rama Reddy

Regional Agricultural Research Station, Acharya N.G.Ranga Agricultural University, Nandyal, Andhra Pradesh 518 502

**Email: plakshmikalyani@gmail.com*

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ABSTRACT

A field experiment was carried out for two consecutive years at the Research farm of Regional Agricultural Research Station, Nandyal during *Kharif* 2016-17 and 2017-18 with an objective to find out the effective and economic method of weed control in Bt cotton. Among different herbicide applications, pendimethalin 1.0 kg/ha as pre-emergence *fb* glyphosate 1.0 kg/ha as directed spray at 2-4 leaf stage weed + one hoeing at 50 DAS were significantly superior in reducing weed density and dry weight of weeds. The crop growth parameters (plant height, no of sympodia per plant), yield attributes (no. of bolls/m^2 andboll weight) and seed cotton yield were recorded highest in weed free check (4.18 t/ ha in 2016 and 3.23 t/ha in 2017) and was comparable with pendimethalin 1.0 kg/ ha as pre-emergence *fb* glyphosate 1.0 kg/ha as directed spray at 2-4 leaf stage weed + one hoeing at 50 DAS. However, the lowest seed cotton yield was recorded under weedy check plot (1.62 t/ha in 2016 and 1.64 t/ha in 2017). Among weed control treatments, highest B:C ratio was recorded with application of pendimethalin 1.0 kg/ha as pre-emergence *fb* glyphosate 1.0 kg/ ha as directed spray at 2-4 leaf stage weed+ one hoeing at 50 DAS closely *fb* weed free check.

INTRODUCTION

Cotton being a wide spaced and relatively slow growing crop during its initial growth stages, suffers from severe weed competition and causing substantial reduction in seed cotton yields upto an extent of 69 per cent (Srinivasulu and Rao 2000). Weed species in cotton field differ widely due to soil and environmental conditions. Weed control, especially during the first eight weeks of cotton growth is essential due to the vulnerability of cotton to early season weed competition. So, use of herbicides is one of the best options to avoid the competition from weeds during the critical period of crop growth. Most often due to incessant rains during *Kharif* season, hand weeding and intercultivation (IC) become difficult in cotton. Further, labours being scarce and costly, growers are forced to fall back on chemicals for weed control. Pre- emergence herbicides at recommended doses are generally capable of controlling annual weeds up to a period of 30 days (Pawar *et al*. 2000). Concentration of these herbicides in soil decreases due to the short half life of herbicide molecules leading to emergence of susceptible weed species beyond 30 days after application of herbicides. In the absence of intercultural and with regular monsoon rains, weeds germinate in different spells and compete with crop plants and finally reduce the seed cotton yield. Hence, there is a need to go for sequential application of pre- emergence followed by post-emergence herbicides to manage the late emerging weeds to eliminate weed competition throughout the critical period (Pawar *et al.* 2000).

Several workers tested the use of post-emergence herbicides like pyrithiobac-sodium (Rao 2011), glyphosate, quizalofop-ethyl (Prabhu *et al.* 2011 and Rao 2011) either alone or in combination. The primary mode of action of pendimethalin is to prevent plant cell division and elongation in susceptible species. Pyrithiobac-sodium inhibits Acetolactase synthase, a key enzyme inbiosynthesis of branched chain amino acids. The productivity of seed cotton in India is 504 kg/ha which is below the world average of 792 kg/ha. In Andhra Pradesh, the cotton crop is being grown in an area of 0.544 million ha with the productivity of 688 kg/ha (Annual Report, AICRP on cotton, 2017-18). This crop is mostly grown in Vertisols of Andhra Pradesh. Hence, present investigation was conducted to study the economics of rainfed Bt cotton as influenced by sequential application of herbicides.

MATERIALS AND METHODS

The field experiment was carried out for two consecutive years at the Research farm of Regional Agricultural Research Station, Acharya N.G Ranga Agricultural University, Nandyal, Andhra Pradesh situated at an altitude of 216 m above mean sea level at 15°29'19'' N latitude and 78° 29'11'' E longitude during *Kharif*, 2016 and 2017 with an a objective to find out the effective and economic method of weed control in Bt cotton. The experiment consists of nine treatments involving various weed management practices in a randomized block design with three replications. The details of treatments were pendimethalin 1.0 kg/ha as pre-emergence + one hoeing, tank mixture (quizalofop-ethyl 50 g/ha+ pyrithiobac-sodium 62.5 g/ha) at 2-4 leaf stage weed + one hoeing, chlorimuron-ethyl 4.0 g/ha at 2-4 leaf stage weed + one hoeing, pendimethalin1.0 kg/ha as pre-emergence + cover crop with sorghum sown at 20 DAS of cotton, pendimethalin 1.0 kg/ha as pre-emergence+ glyphosate 1.0 kg/ha as directed spray at 2-4 leaf stage weed + one hoeing, pendimethalin 1.0 kg/ha as pre-emergence *fb* tank mixture (quizalofop-ethyl 50 g/ha+ pyrithiobac-sodium 62.5 g/ha) at 2-4 leaf stage weed + one hoeing , pendimethalin 1.0 kg/ha as pre-emergence *fb* chlorimuron-ethyl 4.0 g/ha at 2-4 leaf stage weed + one hoeing, weed free check, weedy check.

The experimental site was deep black clay in textural class with low organic carbon (0.39%) and available nitrogen (188.6 kg/ha), medium in available phosphorus (23.6 kg/ha) high in available potassium (480.0 kg/ha) with P_H (8.3), EC (0.09 ds/m). Good viable delinted seeds of '*Jaddoo BG-II*' were dibbled with a spacing of 90 × 45 cm during July. The seed rate adopted was 2.5 kg of delinted seeds/ha. The experimental plots were applied with recommended dose of fertilizers (150:60:60 NPK kg/ha). The entire dose of phosphorus was applied as basal in the form of single super phosphate (16% P_2O_5). Nitrogen in the form of urea (46% N) and potassium (60% K_2O) in the form of muriate of potash were applied in three equal splits at 30,60 and 90 DAS by pocketing method. Herbicides were applied with hand operated knapsack sprayer using a spray volume of 500 l/ha. A total of 800 mm rainfall was received during both the years of study. Pre-emergence herbicides were applied immediately after sowing at proper moisture levels in the soil. Post-emergence herbicides were applied at specified time interval as per the scheduled programme. Weed count was recorded at 30, 60 and 90 DAS using quadrate from each plot and expressed per m^2 and data was subjected to square root transformation $(\sqrt{x+1})$ before statistical analysis to normalize the distribution (Panse and Sukhatme 1978). Weed dry weight was recorded after drying the weed samples at 70°C for 48 h. Weed control efficiency was computed as prescribed by Mani *et al.* (1973) and expressed as percentage. Plant height (cm), number of sympodia per plant, number of bolls/m^2, boll weight (g) were recorded just before harvesting. Three pickings of seed cotton was done from each treatment for recording final yield data.

RESULTS AND DISCUSSION

Weed flora of the experimental field predominantly consisted of six species of broad-leaved weeds, two species of grasses and a sedge. Dominant among grassy weeds were *Panicum repens* (8.3%) and *Dianebra retroflexa* (6.2%). *Euphorbia hirta* (8.0%), *Trianthema portulacastrum* (20.2%), *Cyanotis auxalis* (8.2%), *Digera arvensis* (9.5%), *Abutilon indicum* (10.0%) and *Phyllanthus maderaspatensis* (22.6%) were the dominant broad-leaved weeds. *Cyperus rotundus* (7.0%) was the only sedge present in the experimental fields.

Weed density

All the weed management practices influenced the weed density in cotton in both the years. At 30 DAS, highest weed density was recorded with tank mixture of quizalofop-ethyl 50 g/ha+ pyrithiobac-sodium 62.5 g/ha at 2-4 leaf stage weed + one hoeing, which was comparable with chlorimuron ethyl 4.0 g/ha at 2-4 leaf stage weed + one hoeing. Significantly lower weed density was recorded with pendimethalin 1.0 kg/ha as pre-emergence *fb* tank mixture of quizalofop-ethyl 50 g/ha+ pyrithiobac-sodium 62.5 g/ha at 2-4 leaf stage weed + one hoeing at 50 DAS, which was comparable with all other treatments expect weed free check because of the post-emergence spray at 20 DAS which effectively controlled the weeds and resulted in low weed density at 30 DAS. Almost similar trend was noticed in second year of study in which all the sequential applications were on par with each other. At 60 DAS, higher weed density was observed with pendimethalin 1.0 kg/ha as pre-emergence+ one hoeing treatment and lower weed density was recorded with pendimethalin 1.0 kg/ha as pre-emergence *fb* glyphosate 1.0 kg/ha as directed spray at 2-4 leaf stage weed + one hoeing at 50 DAS, which was comparable with pendimethalin 1.0 kg/ha as pre-emergence *fb* tank mixure (quizalofop-ethyl 50 g/ha + pyrithiobac-sodium 62.5 g/ha) at 2-4 leaf stage weed + one hoeing and tank mixure (quizalofop-ethyl 50 g/ha+ pyrithiobac-sodium 62.5 g/ha) at 2-4 leaf stage

weed + one hoeing treatment during both the years of study. At 90 DAS pendimethalin 1.0 kg/ha as pre-emergence + one hoeing treatment recorded higher weed density, which was comparable with chlorimuron-ethyl 4.0 g/ha at 2-4 leaf stage weed + one hoeing, while lower weed density was noticed with pendimethalin 1.0 kg/ha as pre-emergence *fb* glyphosate 1.0 kg/ha as directed spray at 2-4 leaf stage weed + one hoeing at 50 DAS and on par with other treatments (**Table 1**).

Critical review of the data indicates that sequential application of pre-emergence herbicides *fb* post-emergence application of glyphosate or tank mixture of quizalofop-ethyl + pyrithiobac-sodium reduced the weed density considerably and resulted in lowest weed density among these treatments. The better performance of sequential application might be due to the effective control of weeds at critical stages. The present findings were in conformity with the findings of Singh *et al*. (2003) and Sonawane *et al*. (2014).

Total weed dry matter

Total weed dry matter was recorded at 30, 60 and 90 DAS during both the years of investigation. At 30 DAS all pre-emergence herbicidal treatments were significantly superior over post-emergence herbicides and weedy check. At 60 DAS higher weed dry weight (19.7 g in 2016 and 21.0 g in 2017) was recorded with pendimethalin 1.0 kg/ha as pre-emergence+ one hoeing treatment and significantly lowest weed density was recorded with pendimethalin 1.0 kg/ha as pre-emergence *fb* glyphosate 1.0 kg/ha as directed spray at 2-4 leaf stage weed+ one hoeing at 50 DAS. This could be attributed to reduced weed competition in the initial stage and control of late emerged weeds by sequential spray which lead to lower weed density and lower weed dry matter. Similar findings were reported by Patel *et al*. (2006) and Ahmed and Susheela (2012). At 90 DAS higher weed dry weight (58.0 g in 2016 and 62.0g in 2017) with chlorimuron ethyl 4.0 g/ha at 2-4 leaf stage weed + one hoeing and lowest weed density (16.2 g in 2016 and 16.0 g in 2017) was recorded with pendimethalin 1.0 kg/ha as pre-emergence *fb* glyphosate 1.0 kg/ha as directed spray at 2-4 leaf stage weed+ one hoeing at 50 DAS (**Table 2**).

Weed control efficiency

The weed dry weight was markedly reduced due to application of pendimethalin 1.0 kg/ha as pre-emergence *fb* glyphosate 1.0 kg/ha as directed spray at 2-4 leaf stage weed + one hoeing at 50 DAS, which resulted in higher weed control efficiency (62.0% in 2016 and 63.9% in 2017), which was comparable with that of weed free check (93%). The better performance of these herbicides might be due to the effective control of all type of weeds by the pre-emergence herbicide during initial stages *fb* control of all type of weeds by spraying the directed application of glyphosate due to its systemic action and it made a cover of killed weeds on soil surface which did not allow new weeds to emerge and provided season long control of weeds. This finding is in line with the results of Gnanavel and Babu (2008) (**Table 2**).

Table 1. Weed density as influenced by different weed control treatments

Treatment	Weed density (no./m^2)					
	30 DAS		60 DAS		90 DAS	
	2016	2017	2016	2017	2016	2017
Pendimethalin 1.0 kg/ha as pre-emergence + one hoeing	4.2* (18.0)	4.0 (16.3)	5.4 (29.7)	5.5 (30.3)	6.9 (48.3)	7.3 (53.0)
Tank mixure (quizalofop-ethyl 50 g/ha + pyrithiobac-sodium 62.5 g/ha) at 2-4 leaf stage weed + one hoeing.	7.2 (52.2)	7.3 (53.7)	3.6 (12.7)	3.4 (11.7)	6.4 (40.7)	6.6 (43.2)
Chlorimuron ethyl 4.0 g/ha at 2-4 leaf stage weed + one hoeing	6.8 (47.6)	6.8 (46.3)	4.2 (18.0)	4.3 (18.3)	6.5 (42.3)	6.4 (41.2)
Pendimethalin 1.0 kg/ha as pre-emergence + cover crop with sorghum sown at 20 DAS of cotton	4.5 (20.3)	4.7 (22.3)	3.9 (15.3)	3.8 (14.7)	6.4 (40.7)	7.0 (48.3)
Pendimethalin 1.0 kg/ha as pre-emergence *fb* glyphosate 1.0 kg/ha as directed spray at 2-4 leaf stage weed + one hoeing	4.4 (19.7)	4.3 (18.3)	3.4 (11.3)	3.5 (12.0)	5.8 (34.0)	5.7 (32.0)
Pendimethalin 1.0 kg/ha as pre- emergence *fb* tank mixure (quizalofop-ethyl 50 g/ha + pyrithiobac-sodium 62.5 g/ha) at 2-4 leaf stage weed + one hoeing	4.2 (17.7)	4.2 (17.7)	3.6 (13.0)	3.8 (14.7)	6.2 (38.0)	6.0 (36.0)
Pendimethalin 1.0 kg/ha as pre- emergence *fb* chlorimuron-ethyl 4.0 g/ha at 2-4 leaf stage weed + one hoeing	4.3 (18.3)	4.6 (21.0)	3.9 (15.3)	4.5 (20.3)	6.2 (38.0)	6.2 (38.3)
Weed free check	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)
Weedy check	7.0 (49.7)	7.4 (54.3)	9.2 (84.7)	9.1 (83.3)	10.3 (107.6)	10.6 (111.3)
LSD (p=0.05)	4.9	4.9	3.8	4.2	6.0	6.5

Crop growth parameters

Plant biometric parameters such as plant height and number of sympodia were significantly influenced by weed control treatments during both the years of study. The cotton plants were taller (133.6 cm in 2016 and 156.3 cm in 2017) in weed free check, which was comparable with all the treatments except weedy check (**Table 3**). Excessive vegetative growth was observed during second year due to continuous rainfall in August. Higher number of sympodia per plant was recorded with weed free check, which was comparable with all the treatments except chlorimuron ethyl 4.0 g/ha at 2-4 leaf stage weed + one hoeing.

Yield attributes and yield

The data on yield attributes like number of bolls per square meter and boll weight indicate that the application of pendimethalin 1.0 kg/ha as pre-emergence *fb* glyphosate 1.0 kg/ha as directed spray at 2-4 leaf stage weed+ one hoeing at 50 DAS reduced the weed competition and facilitated the crop plants to utilize the resources like water and nutrients available and resulted in better crop growth, better yield attributes like more number of bolls per square meter and increased boll weight (g) and finally highest seed cotton yield.

Table 2. Weed dry weight and weed control efficiency (WCE) as influenced by different weed control treatments

Treatment	Weed dry weight (g/m^2)						WCE at 90 DAS (%)	
	30 DAS		60 DAS		90 DAS			
	2016	2017	2016	2017	2016	2017	2016	2017
Pendimethalin 1.0 kg/ha as pre-emergence + one hoeing	3.5* (12.5)	3.3 (10.7)	4.4 (19.7)	4.6 (21.0)	6.9 (48.0)	7.3 (53.3)	34	34.2
Tank mixure (quizalofop-ethyl 50 g/ha+ pyrithiobac-sodium 62.5 g/ha) at 2-4 leaf stage weed + one hoeing.	7.3 (52.8)	7.0 (48.7)	3.5 (12.1)	3.9 (15.3)	4.8 (22.7)	4.6 (21.3)	54.3	58.5
Chlorimuron ethyl 4.0 g/ha at 2-4 leaf stage weed + one hoeing	7.4 (54.3)	6.8 (46.7)	4.2 (17.5)	4.0 (15.7)	7.6 (58.0)	7.9 (62.0)	27.6	28.8
Pendimethalin 1.0 kg/ha as pre-emergence + cover crop with sorghum sown at 20 DAS of cotton	3.6 (13.3)	3.5 (12.3)	3.6 (13.2)	3.5 (12.0)	5.6 (31.4)	6.0 (35.7)	46.6	45.9
Pendimethalin 1.0 kg/ha as pre-emergence *fb* glyphosate 1.0 kg/ha as directed spray at 2-4 leaf stage weed + one hoeing	3.8 (14.5)	3.7 (13.7)	3.3 (10.7)	3.3 (11.0)	4.0 (16.1)	4.0 (16.0)	62.0	63.9
Pendimethalin 1.0 kg/ha as pre- emergence *fb* tank mixure (quizalofop-ethyl 50 g/ha + pyrithiobac-sodium 62.5 g/ha) at 2-4 leaf stage weed + one hoeing	3.8 (14.3)	3.8 (14.7)	4.0 (15.8)	3.8 (14.7)	6.2 (39)	6.0 (35.7)	41.0	45.9
Pendimethalin 1.0 kg/ha as pre- emergence *fb* chlorimuron-ethyl 4.0 g/ha at 2-4 leaf stage weed + one hoeing	3.6 (13.2)	3.8 (14.3)	4.1 (16.7)	4.0 (15.7)	6.3 (40)	6.5 (42.5)	40.0	41.4
Weed free check	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	0.7 (0.0)	93.3	93.6
Weedy check	7.2 (51.7)	7.3 (52.9)	9.4 (87.6)	9.1 (82.3)	10.5 (109.6)	11.1 (124.0)	0	0
LSD (p=0.05)	3.4	4.7	2.1	3.6	6.3	6.5		

*Data were subjected to square root formation $(\sqrt{x+1})$. Data given in parentheses are original value. DAS- Days after sowing

Table 3. Growth characters and Seed cotton yield as influenced by different weed control treatments

Treatment	Plant height (cm)		No. of sympodia at harvest		No. of Bolls/m^2		Boll weight (g)		Seed cotton yield (t/ha)	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Pendimethalin 1.0 kg/ha as pre-emergence + one hoeing	120.3	146.7	17.1	14.8	66.3	47.0	4.76	4.37	3.21	2.20
Tank mixure (quizalofop-ethyl 50 g/ha + pyrithiobac-sodium 62.5 g/ha) at 2-4 leaf stage weed + one hoeing.	124	132.0	19.3	15.5	60.0	46.0	5.02	4.02	2.70	2.23
Chlorimuron-ethyl 4.0 g/ha at 2-4 leaf stage weed + one hoeing	124	137.7	15.8	16.3	61.6	44.4	4.18	4.02	2.61	2.31
Pendimethalin 1.0 kg/ha as pre-emergence + cover crop with sorghum sown at 20 DAS of cotton	122.2	143.3	16.2	17.3	65.3	53.5	4.74	4.33	3.13	2.06
Pendimethalin 1.0 kg/ha as pre-emergence *fb* glyphosate 1.0 kg/ha as directed spray at 2-4 leaf stage weed + one hoeing	128.0	144.7	20.0	18.0	79.6	61.0	5.15	4.43	4.18	2.78
Pendimethalin 1.0 kg/ha as pre-emergence *fb* tank mixure (quizalofop-ethyl 50 g/ha + pyrithiobac-sodium 62.5 g/ha) at 2-4 leaf stage weed + one hoeing	126.3	136.3	19.1	16.7	69.8	56.7	5.12	4.37	3.62	2.70
Pendimethalin 1.0 kg/ha as pre-emergence *fb* chlorimuron-ethyl 4.0 g/ha at 2-4 leaf stage weed + one hoeing	122.6	132.0	19.1	15.7	68.3	52.1	4.82	3.92	3.20	2.25
Weed free check	133.6	156.3	20.3	19.0	80.0	67.8	5.23	4.60	4.18	3.23
Weedy check	92.0	89.3	13.0	13.0	48.0	43.6	3.38	2.97	1.62	1.64
LSD (p=0.05)	17.5	25.8	3.6	2.5	16.7	10.4	0.8	0.86	0.72	0.54

Table 4. Economics as influenced by different weed control treatments

Treatment	Cost of weeding (x10³ `/ha)		Cost of cultivation (x10³ `/ha)		Gross returns (x10³ `/ha)		Net returns (x10³ `/ha)		B:C ratio	
	2016	2017	2016	2017	2016	2017	2016	2017	2016	2017
Pendimethalin 1.0 kg/ha as pre-emergence + one hoeing	6.12	6.42	52.62	53.42	176.71	99.13	124.09	45.71	3.4	1.9
Tank mixure (quizalofop-ethyl 50 g/ha + pyrithiobac-sodium 62.5 g/ha) at 2-4 leaf stage weed + one hoeing.	8.47	8.72	54.97	55.72	148.61	100.44	93.63	44.71	2.7	1.8
Chlorimuron ethyl 4.0 g/ha at 2-4 leaf stage weed + one hoeing	5.27	5.67	51.77	52.67	143.38	103.90	91.61	51.23	2.8	2.0
Pendimethalin 1.0 kg/ha as pre-emergence + cover crop with sorghum sown at 20 DAS of cotton	6.32	6.50	52.82	53.50	172.04	92.74	119.21	39.24	3.3	1.7
Pendimethalin 1.0 kg/ha as pre-emergence *fb* glyphosate 1.0 kg/ha as directed spray at 2-4 leaf stage weed + one hoeing	6.00	6.20	52.50	53.20	229.73	125.01	177.23	71.81	4.4	2.3
Pendimethalin 1.0 kg/ha as pre-emergence *fb* tank mixure (quizalofop-ethyl 50 g/ha + pyrithiobac-sodium 62.5 g/ha) at 2-4 leaf stage weed + one hoeing	9.60	9.80	56.10	56.80	198.93	121.59	142.83	64.79	3.5	2.1
Pendimethalin 1.0 kg/ha as pre-emergence *fb* chlorimuron-ethyl 4.0 g/ha at 2-4 leaf stage weed + one hoeing	6.39	6.89	52.89	53.89	176.00	101.47	123.10	47.58	3.3	1.9
Weed free check	14.00	14.60	60.50	61.60	230.12	145.57	169.62	83.97	3.8	2.4
Weedy check	0	0	46.50	47.00	89.37	73.84	42.87	26.84	1.9	1.6

Seed cotton yield was significantly influenced by the weed control treatments in both the years (**Table 3**). Higher seed cotton yield (4.2 t/ha in 2016 and 3.2 t/ha in 2017) was recorded with weed free check and was on par with pendimethalin1.0 kg/ha as pre-emergence *fb* glyphosate 1.0 kg/ha as directed spray at 2-4 leaf stage weed + one hoeing at 50 DAS and pendimethalin 1.0 kg/ha as pre-emergence *fb* tank mixture of quizalofop-ethyl 50 g/ha+ pyrithiobac-sodium 62.5 g/ha at 2-4 leaf stage weed + one hoeing (Nayak BS *et al*. 2016). Lower seed cotton yield (1.6 t/ha and 1.6 t/ ha in 2016 and 2017, respectively) was recorded with weedy check.

Higher cost of cultivation (60.5 x10³ `/ha and 61.6 x10³ `/ha in 2016 and 2017, respectively) was recorded with weed free check and lowest with weedy check. Higher net returns (169.62 x10³ `/ha and 83.97x10³ `/ha in 2016 and 2017, respectively) and B:C ratio (4.4 and 2.3 in 2016 and 2017, respectively) was recorded with pendimethalin 1.0 kg/ha as pre-emergence *fb* glyphosate 1.0 kg/ha as directed spray at 2-4 leaf stage weed + one hoeing at 50 DAS, which is similar to the trend of weed free check (**Table 4**).

It may be concluded that sequential application of pendimethalin 1.0 kg/ha as pre-emergence *fb* glyphosate 1.0 kg/ha as directed spray at 2-4 leaf stage weed + one hoeing at 50 DAS provide effective and economical weed control during the critical period of crop weed competition in Bt cotton.

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