Efficacy of chemical weed management in *Bt* cotton (*Gossypium hirsutum* L.)

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ABSTRACT

A field experiment was conducted during growing season of 2012-13 at Agricultural College Farm, Bheemarayanagudi, Shahapur (Karnataka) under UKP command area to develop an effective weed management strategy. The experiment comprised of 14 treatments having two PRE (diuron, pendimethalin) and five POST (propaquizafop, quizalofop ρ tefuryl, fenoxaprop ρ ethyl, quizalofop ethyl and pyrithiobac sodium applied twice at 20 and 40 DAS individually or in sequence with pendimethalin PRE) herbicides and weedy and weed-free check. Among the post emergence herbicides, pyrithiobac sodium 10 EC used alone twice or in sequence with pendimethalin PRE recorded lower weed dry weight and higher weed control efficiency throughout. Of all the treatments, pendimethalin 38.7 CS @ 1.5 kg a.i. ha^{-1}PRE fb pyrithiobac sodium 10 EC @ 1.25 kg a.i. ha^{-1} POST + IC at 60 DAS recorded the lowest weed dry matter, weed index, nutrient depletion, highest seed cotton yield (2,569 kg ha^{-1}) and gross returns (1,07,885 Rs. ha^{-1}). Pendimethalin 38.7 CS PRE followed with quizalofop ethyl 5 EC @ 0.05 kg a.i. ha^{-1}or propaquizalofop 10 EC @ 0.1 kg a.i. ha^{-1} at 30-35 DAS were the next efficient treatments.

Keywords: *Bt* cotton, pre and post-emergent herbicides, weed dry weight, weed index, nutrient depletion, seed cotton yield

INTRODUCTION

Weed problem is a serious production constraint in cotton, which may cause yield loss from 40 to 85 per cent depending upon the nature and intensity of weeds. 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. Therefore, there is need for selective broad spectrum herbicides. Now, Pendimethalin and diuron are recommended as selective and conspicuous pre-emergent herbicides being used in weed control programmes in cotton to control annual grasses and broad leaf weeds at early stage of the crop. Present recommendation of pre emergence herbicide (pendimethalin) application followed by two or three IC is a common practice [1]. However, most often the incessant rains during *kharif* and frequent and heavy irrigations in irrigation commands make IC a difficult proposition particularly in black cotton soils. Therefore, farmers are need of selective post emergence broad spectrum herbicide/herbicide mixtures. Pyrithiobac sodium and graminicides (Propaquizafop, quizalofop ρ

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tefuryl, fenoxaprop ρ ethyl and quizalofop ethyl) are systemic herbicides with a specific target site of action. These graminicides are Acetyl CoA carboxilase (ACCase) inhibitors, a key enzyme in biosynthesis of fatty acids and hence results in the death of weeds [1]. Phyrithiobac is a broad spectrum systemic herbicide, which inhibits enzyme acetolacetate synthase, a key enzyme in biosynthesis of branched chain amino acids. It is reported to control troublesome broadleaf weeds when applied as pre-plant incorporation (PPI), pre-emergence (PRE) and post emergence (POE at 2-3 leaf stage) without affecting the cotton [2]. Therefore, the present research was conducted to develop an effective weed management system involving pre and post emergence herbicides either singly or in sequence along with intercutlivation as an economically feasible alternative in cotton.

MATERIALS AND METHODS

The field experiment was conducted during *Kharif* of 2012-13 at Agricultural College Farm, Bheemarayanagudi, Shahapur (Karnataka) under UKP Command area. The soil of experimental site was medium deep black soil, medium in organic carbon (0.7%), low in available nitrogen (252 kg ha^{-1}), medium in available phosphorus (33 kg ha^{-1} P_2O_5) and high in potash (297 kg ha^{-1} K_2O). The experiment comprised of 14 treatments, viz., unweeded check (T_1), weed-free check (T_2), diuron 80 WP (@ 1 kg a.i. ha^{-1} PRE fb IC and HW at 30, 45 and 60 DAS, T_3), pendimethalin 38.7 CS (@ 0.68 kg a.i. ha^{-1} PRE fb IC and HW at 45 DAS, T_4), propaquizafop 10 EC (@ 0.1 kg *a.i.* ha^{-1} POE at 20 and 40 DAS fb IC at 60 DAS, T_5), quizalofop ρ tefuryl 4.41 EC (@ 0.044 kg a.i. ha^{-1} POE at 20 and 40 DAS + IC at 60 DAS, T_6), fenoxaprop ρ ethyl 9.3 EC (@ 0.1 kg a.i. ha^{-1} POE at 20 and 40 DAS fb IC at 60 DAS, T_7), quizalofop ethyl 5 EC (@ 0.05 kg a.i. ha^{-1} POE at 20 and 40 DAS fb IC at 60 DAS, T_8), pyrithiobac sodium 10 EC (@ 0.125 kg a.i. ha^{-1} POE at 20 and 40 DAS fb IC at 60 DAS, T_9), pendimethalin PRE fb propaquizafop 10 EC @ 0.1 kg a.i. ha^{-1} POE at 30-35 DAS fb IC at 60 DAS (T_{10}), pendimethalin PRE fb quizalofop ρ tefuryl 4.41 EC @ 0.044 kg a.i. ha^{-1} POE at 30-35 DAS fb IC at 60 DAS (T_{11}), pendimethalin PRE fb fenoxaprop ρ ethyl 9.3 EC @ 0.1 kg a.i. ha^{-1} POE at 30-35 DAS fb IC at 60 DAS (T_{12}), pendimethalin PRE fb quizalofop ethyl 5 EC @ 0.05 kg a.i. ha^{-1} POE at 30-35 DAS fb IC at 60 DAS (T_{13}), and pendimethalin PRE fb pyrithiobac sodium 10 EC @ 0.125 kg a.i. ha^{-1} POE at 30-35 DAS fb IC at 60 DAS (T_{14}). The experiment was laid out in a randomized complete block design with three replications. Cotton (cv. Arya *Bt* BG II) was sown on 10th July of 2012 with a spacing of 90 cm × 60 cm. Fertilizer application (150:75:75 kg ha^{-1} N, P_2O_5 and K_2O) was as per the recommendation. The crop was irrigated twice at 20 days interval after cessation of monsoon. Crop prophylactic measures were taken as and when necessary. The weed density, dry matter of weeds and weed control efficiency were evaluated besides observations on cotton dry matter accumulation, seed cotton yield, gross return, and B:C ratio and the data were subjected for statistical analysis and interpretation.

RESULTS AND DISCUSSION

Weed dry matter per unit area is the better index than weed density to evaluate the negative impact of weeds on crops [3]. In the present weed management investigation, the dry weight of weeds reduced significantly due to different weed management practices (Table 1). At 20 DAS, the lowest dry weight of weeds (1.22 g m^{-2}) was recorded in recommended practice (T_3) followed by T_4. This might be due to the decreased weed population under these herbicides. The reason for lower weed dry weight at 40 DAS might be due to sequential herbicidal application. Therefore, among sequential application of herbicides at 40 DAS, pendimethalin fb pyrithiobac sodium recorded significantly lower weed dry weight (1.08 g m^{-2}) and was nearly on par with pendimethalin fb quizalofop ethyl, pendimethalin fb propaquizafop which were significantly superior to all other

treatments (Table 1). It indicates that sequential application of PRE and POST emergent herbicides supplemented with IC at 60 DAS was superior to other treatments. Similar results were reported earlier by [1]. The beneficial effects were extended up to 60 DAS. Post emergent herbicides except pyrithiobac sodium sprayed alone twice at 20 and 40 DAS failed to reduce the weed dry weight in comparison to sequential application. This might be due to the fact that part of the weeds that were emerged earlier could be resistant to the first post spray of POE chemicals at the rate and time applied as revealed by weed dry matter before the first POST.

Table 1. Weed dry weight, weed control efficiency and weed index as influenced by different weed control treatments in *Bt* cotton.

Treatments	Dry weight of weeds (g m^{-2})				Weed control efficiency (%)				Weed index (%)
	20 DAS	40 DAS	60 DAS	At harvest	20 DAS	40 DAS	60 DAS	At harvest	
T_1	1.54 (32.77)*	2.23 (168.99)	2.35 (224.29)	2.23 (167.37)	0.00	0.00	0.00	0.00	45.15
T_2	0.30 (0.00)	0.30 (0.00)	0.30 (0.00)	0.30 (0.00)	100.00	100.00	100.00	100.00	0.00
T_3	1.22 (14.50)	1.56 (34.32)	2.00 (98.69)	1.87 (75.30)	55.73	79.73	51.53	53.19	26.61
T_4	1.27 (16.49)	1.95 (86.25)	2.07 (116.20)	1.94 (86.12)	49.70	48.94	42.67	44.34	31.65
T_5	1.53 (31.80)	1.69 (47.47)	1.65 (42.36)	1.63 (41.11)	2.93	71.83	79.05	80.71	25.56
T_6	1.54 (32.35)	1.81 (62.96)	1.70 (48.32)	1.69 (46.74)	1.25	62.75	76.19	77.86	36.88
T_7	1.52 (31.43)	1.83 (65.96)	1.72 (50.03)	1.69 (47.72)	4.14	60.98	75.27	77.27	38.25
T_8	1.52 (30.80)	1.68 (46.46)	1.67 (44.98)	1.64 (42.19)	6.02	72.41	77.82	79.16	24.67
T_9	1.51 (30.61)	1.62 (40.19)	1.58 (36.32)	1.51 (30.58)	6.61	76.20	82.05	83.38	20.89
T_{10}	1.26 (16.25)	1.29 (17.52)	1.52 (31.66)	1.46 (27.38)	50.40	89.62	81.95	85.95	12.35
T_{11}	1.28 (17.21)	1.42 (24.56)	1.63 (40.89)	1.59 (37.82)	47.54	85.49	78.97	80.97	24.25
T_{12}	1.26 (16.47)	1.40 (25.99)	1.66 (44.26)	1.62 (39.79)	49.83	84.46	77.83	80.17	25.06
T_{13}	1.29 (17.55)	1.27 (16.86)	1.49 (29.56)	1.45 (26.08)	46.43	90.03	83.21	82.77	9.69
T_{14}	1.30 (17.86)	1.08 (10.09)	1.43 (25.92)	1.34 (20.15)	45.41	94.02	87.61	88.61	7.19
S.Em±	0.02	0.05	0.03	0.04	2.57	1.58	2.89	3.19	3.92
CD at 5%	0.06	0.14	0.10	0.11	7.47	4.59	8.40	9.28	11.39

*Figures in the parenthesis are original values; data subjected for transformation using log (x+2), where x is weed dry matter.

At harvest, the lower weed biomass (1.34 g m^{-2}) was registered in pendimethalin - pyrithiobac sodium as pre- and post emergent application + IC (T_{14}) which was on par with pendimethalin - quizalofop ethyl and pendimethalin - propaquizafop integrated with IC (1.45 g m^{-2} and 1.46 g m^{-2} to T_{13} and T_{11} respectively). At this period weeds might be reduced by smothering effect of well established crop canopy. As a consequence of variation in weed count (not explained here) and in weed density; weed control efficiency varied significantly among treatments (Table 1). At 20 DAS, the highest weed control efficiency was recorded with diuron 80 WP @ 1kg a.i. ha^{-1} (55.73%) and pendimethalin 38.7 CS @ 0.68 kg a.i. ha^{-1} (49.70%). This fact highlights importance of effectiveness of both chemicals at early growth stage of cotton. Diuron helps the crop to establish better and make early growth under weed free situation and pendimathalin also had similar effects. However, pre emergent herbicides were not effective in controlling the weeds for longer period [4],

the results of experiments conducted earlier [1,4] also obeyed that sequential use of pre emergent and post emergent herbicides controlled weeds effectively. In the present study also, at 40 DAS, the maximum weed control efficiency was observed in T_{14} (94.02%) which was on par with T_{13} (90.03%) and pendimethalin fb propaquizafop + IC (89.62%) and same trend followed upto 60 DAS. At picking stage, the highest weed control efficiency was observed with T_{14} (88.61%); and twice application of pyrithiobac sodium at 20 and 40 DAS + IC (83.38%) was at par. Weed index is directly influenced by weed population and weed dry weight [1]. Therefore, consequent upon reduced weed density and dry matter pendimethalin and pyrithiobac sodium + IC recorded the lowest weed index (7.19%) which was on par with (9.69% and 12.35%, respectively) treatments where quizalofop ethyl or propaquizafop was used in sequence with pendimethalin along IC. Similar results were reported by [1]. Herbicides alone or in combination with one hand weeding reduce the weed dry weight and nutrient uptake by weeds significantly [5]. Similarly in the present investigation there was noticeable decrease in nitrogen depletion by weeds (Table 2). N depletion was significantly lower (15.57 kg ha^{-1} & 15.87 kg ha^{-1}) in pendimethalin - pyrithiobac sodium followed with IC and in diuron + IC + HW thrice, respectively. In P uptake, pendimethalin - pyrithiobac sodium coupled with one IC recorded significantly reduced P uptake (2.93 kg ha^{-1}) by weeds followed by pendimethalin - quizalofop + IC (3.13 kg ha^{-1}). Similar trend was also found in K removal by weeds. In other treatments increased nutrient depletion was due to higher dry weight of weeds. Therefore, maximum depletion of nutrient removal by weeds was recorded under unweeded condition (83.77 kg N ha^{-1}, 18.13 kg P ha^{-1} and 88.20 k ha^{-1}). Similar results were also reported by [6]. Higher total dry matter production (TDMP) of cotton was observed in weed-free check (471.3 g $plant^{-1}$) while it was the lowest with unweeded check (328.77 g $plant^{-1}$) (Table 2). Higher dry matter production with the former treatment was due to higher accumulation of photosynthates in leaves, stem and reproduction parts. The increase in plant height and TDMP due to different weed management practices resulted into increased seed cotton yield. Hence, integrated weed management plays a vital role in achieving potential yield of crop. Therefore, among the herbicidal treatments, pendimethalin fb pyrithiobac sodium + IC treatment recorded the highest dry matter production (461.35 g $plant^{-1}$) and it was at par with other integrated treatments like pendimethalin fb quizalofop ethyl + IC and pendimethalin fb propaquizalofop + IC (451.54 and 447.06 g $plant^{-1}$ respectively).

Table 2. Nutrients depletion, seed cotton yield, gross yield and B:C ratio as influenced by different weed control treatments in *Bt* cotton.

Treatments	Nutrient depletion by weeds (Kg ha^{-1})			Dry matter accumulation of cotton (g $plant^{-1}$)	Seed cotton yield (kg ha^{-1})	Gross return (Rs ha^{-1})	B:C
	N	P	K				
T_1	83.77	18.13	88.20	328.77	1478	62072	2.30
T_2	0.00	0.00	0.00	471.30	2695	113187	3.06
T_3	15.87	3.53	22.67	421.34	1977	83046	2.81
T_4	16.37	3.77	23.30	426.50	1839	77231	2.74
T_5	18.27	4.37	25.90	381.44	2007	84277	2.70
T_6	18.73	4.20	25.23	360.32	1701	71444	2.47
T_7	19.07	4.17	26.07	355.39	1655	69508	2.26
T_8	17.77	4.07	25.53	380.91	2020	84848	2.89
T_9	17.40	3.50	24.53	394.29	2128	89359	2.60
T_{10}	16.67	3.43	23.70	447.06	2361	99177	3.23
T_{11}	16.97	3.30	24.10	428.86	2032	85340	2.89
T_{12}	17.17	3.27	23.33	424.96	2018	84767	2.79
T_{13}	16.23	3.13	22.90	451.54	2333	97974	3.29
T_{14}	15.57	2.93	22.10	461.35	2569	107885	3.35
S.Em±	0.58	0.10	0.27	6.95	105.2	4409	0.14
CD at 5%	1.69	0.28	0.87	20.20	305.3	12817	0.42

Seed cotton yield differed significantly due to weed control treatments. The highest seed cotton yield was produced in weed free check (2695 kg ha^{-1}). Among the herbicidal treatments, pendimethalin fb pyrithiobac sodium + IC recorded significantly higher seed cotton yield (2569 kg ha^{-1}). Treatments receiving pendimethalin fb quizalofop ethyl + IC (2333 kg ha^{-1}) and pendimethalin fb propaquizafop + IC (2361 kg ha^{-1}) were also on par with it. The lowest seed cotton yield was obtained in unweeded check (1478 kg ha^{-1}). In unweeded check the competition from weeds prevailed for the entire season and hence reduced the seed cotton yield by 82.3, 73.8, 59.7 and 57.8 per cent over weed free check, T_{14}, T_{13} and T_{10} respectively. The increased seed cotton yields in sequential herbicidal applications (T_{14}, T_{13}, T_{10}) along with intercultivation can be attributed to weed free/low weed situation during initial stage and further control of new growth of weeds by application of post emergence herbicides at 30-35 DAS followed by physical method of control through intercultivation at 60 DAS and thus, reducing the weed competition during critical initial to peak growth period of the crop. In fact, intercultivation operation carried out at 60 DAS almost maintained weed free condition throughout remaining period of crop growth period.

The maximum gross return was obtained in weed free check (Rs. 1, 13,187) which was on par with pendimethalin + pyrithiobac + intercultivation (Rs. 1,07,885) and treatments T_{10} (99,177) and T_{13} (97,974) were next to it respectively. The net return per rupee spent was also highest in pedimethalin followed by pyrithiobac sodium coupled with one intercultivation (3.35) and treatments T_{13} (3.29) and T_{10} (3.42) were on par to it. Even though the weed free check had at par B:C ratio (3.06), it is quite important to note that keeping the land free of weeds throughout the crop growing period is practically impossible for the farmers since it involves huge cost on labour. Added to this, the availability to working force in the villages has been considerably reduced due migration to the cities and availability of required labours force at particular crop growth stage is also difficult due to requirement of one time needs by many farmers. The continuous rains during particular crop growth period further aggravate the situation even though the labour force is available. Besides it is also found that weeds cause considerable losses by the time they are removed, thus reflecting on seed cotton yields. This is also partly applicable in integrated and farmers weed control methods. [7]. Under these circumferences an alternative and economical weed control method is sequential application of pendimethalin and pyrithiobac sodium + intercultivation, which was on par with weed free check and was found to be best method of weed management.

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