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EVALUATION OF EFFECTIVE WEED MANAGEMENT STRATEGY FOR BT COTTON

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ABSTRACT

A field experiment was conducted at Agricultural Research Station, Banswara (Raj.) during *rainy* season of 2014 to evaluate effective weed management strategy for Bt cotton. The experiment consisted of 9 treatments of PE (Pendimethalin) and POE (Quizalofop ethyl, pyrithiobac sodium and glyphosate) herbicides with weed free and weedy checks was laid out in randomized block design with three replications. Results revealed that the sequential use of pendimethalin 30 EC @1.0kg a.i ha^{-1} (PE) followed by pyrithiobacsodium 10 EC @ 62.5g a.i ha^{-1} + Quizalofop ethyl 5 EC @ 50g a.i ha^{-1}(POE) at 25 DAS with one hoeing at 45 DAS has resulted in the lowest weed density of 19.67 and 12.33 with lowest weed dry weight of 15.73 and 10.13 g m^{-2} recorded at 30 and 60 DAS, respectively with the lowest total weed dry matter of 258.56kg ha^{-1}, which ultimately increased seed cotton yield significantly (4389kg ha^{-1}) with maximum B: C ratio of 4.74 against 3.98 calculated in weed free plot. The highest weed control efficiency of 96.08% was calculated under this treatment.

INTRODUCTION

India is a second largest cotton producing country in the world (AICCIP, 2014). It plays important role in the Indian economy involving about 60 million people in cotton cultivation, textile industries and trade. Transgenic Bt cotton technology since its first commercialization in 2002 has been widely accepted by cotton growers in the country as it has generated economic benefits by reducing insecticides requirement and contributed to produce higher yield. Cotton being a wide row rainy season crop with heavy doses of fertilizer attracts huge weeds competition during early crop growth stages (Venugopalan *et al.*, 2012). Weedy infestation in cotton is a major biotic constraint which reduce cotton yield by 40 to 85 % (Nalayini and Kandasamy, 2013). The critical period of crop-weed competition in cotton was reported to be from 15 to 60 days after sowing (Sharma, 2008). Weeds not only compete with crop for water, nutrient, light and space but also provide harbour for insect pests. The practice of repeated hand weeding and inter-culture is still widely practiced however; incessant rains impede both manual and cultural weeding operation in time. Therefore, the use of PE and POE herbicides with some amount of mechanical operation would necessary to keep the crop safe during initial crop growth stage. Herbicides like alachlor, fluchlorin, diuron, fenuron, MSMA alone or in combination applied at pre-planting, pre-emergence and post emergence stages were widely evaluated but no single combination was found uniformly effective.

Presently, the use of pendimethalin herbicide as pre-emergence spray followed by two manual weeding with one intercultural operation is a common practice for weed control in cotton in Southern Rajasthan. The effects of pre-emergence herbicides do not last for longer period results to poor weed control efficiency. Only mechanical weeding is also partially ineffective because weeds also grow in intra rows space. Incessant rains during early growth stages make the manual weeding impossible and application of glyphosate as directed spray in standing crop causes plant injury (Srinivasulu and Rao, 2000 and Mahar *et al.*, 2007) resulting in to ineffective weed control. The present study therefore, was conducted to evaluate effective weed management strategy for Bt. cotton in Southern Rajasthan.

MATERIALS AND METHODS

Experimental site and meteorological information

A field experiment was conducted at Agricultural Research Station, Banswara during *kharif*, 2014 to study the effective weed management strategy for Bt cotton in SouthernRajasthan, India.The climatic condition of Banswara remains humid throughout the season and located at 23° 33′ N latitude, 74°27′E longitude at an altitude of 220 MSL. The soil of the experimental field was clay loam in texture, low in available N, medium in available P and high in available K with pH value of 7.8.

Technical programme

The treatments comprising of application of pendimethalin 30 EC @ 1.0 kg a.i. ha^{-1} (PE) + one hoeing at 45 DAS (T_1), Quizalofop ethly 5EC @ 50 g a.i. ha^{-1} at 25 days after sowing (DAS) + one hoeing (T_2), Pendimethalin 30EC@ 1.0 kg a.i.ha^{-1} followed by Quizalofop ethyl 5EC @ 50 g a.i/ha at 25 DAS + one hoeing at 45 DAS (T_3),Pyrithiobac sodium 10EC @ 62.5g

a.i.ha^{-1} at 25DAS + one hoeing at 45 DAS (T_4), Pyrithiobac sodium @ 62.5g a.i.ha^{-1} + Quizalofop ethyl 5EC @ 50g a.i. ha^{-1} 25 DAS +one hoeing at 45 DAS (T_5), Pendimethalin 30 EC @ 1.0 a.i. ha^{-1} (PE) followed by Pyrithiobac sodium 10EC@ 62.5g a.i.+ Quizalofop ethyl @ 50 g a.i. ha^{-1} at 25 DAS +one hoeing at 45 DAS (T_6), Glyphosate 41SL @ 1.0 kg a.i. ha^{-1} as directed spray at 45 DAS (T_7), Weed free (T_8) and weedy check (T_9) were allocated in Random Block Design with three replications. The cotton hybrid Jai Bt was sown on 10th June at standard geometry of 90 × 45cm. Fertilizers were applied uniformly as per recommendation (120:60:30 kg NPK ha^{-1}) in all plots. The full dose of P and K and half dose of N were applied as basal dose and remaining dose of N was applied in two splits at square formation and boll development stages. Pendimethalin,the pre-emergence (PE) herbicide was applied just after sowing and quizalofop ethyl and pyrithiobac sodium, post-emergence (POE) herbicides were sprayed at 25 DAS with a knapsack sprayer fitted with a flat fan nozzle using a spray volume of 500 l ha^{-1}.

Observations on weeds

Weed density

The weed count was recorded specie-wise using 1.0 m × 1.0 m quadrat from three random places in each plot and the weeds falling within the frames of the quadrat were counted and the mean values were expressed in number·m^{-2}. The densities of grasses, sedges and broad leaved weeds and the total weeds were recorded at 30 and 60 days after sowing and expressed in number·m^{-2}.

Weed dry weight

The weeds falling within the frames of the quadrat were collected, categorized into grasses, sedges and broad leaved weeds, shade dried and later dried in hot-air oven at 80°C for 72 hrs. The total dry weight of grasses, sedges and broad-leaved weeds recorded at 30, 60 days after sowing and at harvesting and expressed in g m^{-2} and total dry weight of weeds of each treatment plots was express in kg ha^{-1}.

Weed Control Efficiency

Weed control efficiency (WCE) was calculated as per the procedure given by Main *et al.* (2010).

$$WCE\% = \frac{WDc - WDt}{WDc} X\ 100$$

Whrere

WCE: weed control efficiency (%).

WDc: weed dry weight (kg ha^{-1}) in control plot.

WDt: weed dry weight (kg ha^{-1}) in treated plot.

Observations and analysis of data

Regarding agronomic characters, ten competitive plants were randomly selected from each plot and observations were recorded for growth and yield attributes. Whereas, seed cotton yield obtained from the net plot area at each picking was recorded and expressed in kg ha^{-1}. Economics was calculated on the basis of market price of seed cotton and cost of cultivation. The data were statistically analyzed following the procedure given by Gomez and Gomez (2010) for randomized block design.

RESULTS AND DISCUSSION

The weed flora of the experimental field indicated the presence of 60% grassy weeds and 40% broad leaved weeds. *Echinochloa colonum*, *Echinochloa crusgalli*, *Eleusine indica*, *Panicum repense*, *Eragrostis sp. Digitaria ramose*, *Dinebra retroxa*, *Cynodon datylon*, *Cyperus rotundus*, *Sorghum helepense* were dominat grassy species while *Trianthema portulacastrum*, *Commelina benghalensis*, *Amaranthus viridis*, *Cleome viscosa*, *Alternenthera echinata*, *Euphorbia genicullata*, *Euphorbia hirta*, *Phylanthus niruri*, *Digera*

Table 1: Effect of weed management on weed density, dry weight and weed control efficiency

Treatment	Weeds m^{-2} at 30 DAS	Weeds dry wt. (g m^{-2}) at 30DAS	Weedsm^{-2} at 60DAS	Weeds dry wt. (gm^{-2}) at 60 DAS	Total weed dry matter (kg ha^{-1})	Weed control efficiency (%)
T_1:Pendimethalin 30 EC @ 1.0 kg a.i.ha^{-1} as PE + one hoeing at 45 DAS	213.3	202.7	65.7	78.8	2815	57.20
T_2: Quizalofop_ethyl 5 EC@50g a. i.ha^{-1} POE at 25 DAS + one hoeing at 45 DAS	87.7	87.43	54.3	57.9	1453	77.90
T_3: Pendimethalin 30 EC@1.0 kg a.i ha^{-1} PE followed by Quizalofop ethyl 5EC @ 50g a.i.ha^{-1} POE at 25 DAS + one hoeing at 45 DAS	72.0	66.97	41.0	42.6	1096	83.34
T_4: Pyrithiobac sodium 10 EC @ 62.5g a.i.ha^{-1} POE at 25 DAS + one hoeing at 45 DAS	125.3	110.30	53.7	48.3	1586	75.89
T_5: Pyrithiobac sodium 10 EC @ 62.5g a.i.ha^{-1} + Quizalofop ethyl 5 EC@50g a.i.ha^{-1} POE at 25 DAS + one hoeing at 45 DAS	51.3	43.63	21.3	17.7	613	90.68
T_6: Pendimethalin 30 EC @1.0 kg a.i.ha^{-1} as PE followed by Pyrithiobac sodium 10EC @ 62.5g a.i. ha^{-1} + Quizalofop ethyl 5EC @ 50g a.i. ha^{-1} POE at 25 DAS + one hoeing at 45 DAS	19.67	15.73	12.33	10.13	258.46	96.08
T_7: Glyphosate 41SL @ 1.0 kg a.i. ha^{-1} as directed spray at 45 DAS	258.7	253.50	110.0	157.7	4112	37.52
T_8: Weed free	0.00	0.00	0.0	0.0	0.00	100.00
T_9: Weedy check	257.3	252.2	414.0	405.7	6579	0.00
CD (p = 0.05)	15.4	15.83	17.60	16.30	192	

Table 2: Effect of weed management on plant height, yield attributes and seed cotton yield

Treatment	Plant height (cm)	Bolls plant^{-1}	Boll wt (g)	Seed cotton yield (kg ha^{-1})
T_1	138.33	43.67	4.25	2558
T_2	143.67	47.33	4.43	3150
T_3	154.33	65.67	4.52	3525
T_4	136.33	41.67	4.28	2873
T_5	157.33	67.67	4.95	3989
T_6	168.00	75.68	5.05	4389
T_7	139.00	38.67	4.22	2233
T_8	175.33	74.33	5.07	4630
T_9	112.33	25.33	4.10	1304
CD (P = 0.05)	8.81	7.70	0.25	283

Table 3: Effect of weed management on economics of Bt cotton

Treatment	Cost of cultivation (Rs ha^{-1})	Gross return (Rs ha^{-1})	Net return (Rs ha^{-1})	B:C ratio
T_1	27000	102309	75309	2.79
T_2	27616	125988	98372	3.56
T_3	29010	141012	112002	3.86
T_4	27183	114932	87749	3.23
T_5	28793	159549	130756	4.54
T_6	30593	175568	144975	4.74
T_7	25600	89340	63740	2.49
T_8	37200	185185	147985	3.98
T_9	20200	52148	31948	1.58
CD (P = 0.05)		11312	11312	0.41

arvensis, *Abutilon indicum, Eclipta alba*, *Achalypha indica*, *Parthenium hysterophorus*, *Xanthium strumarium*, *Tribulus terrestris*, *Acaranthus aspera* were dominated broad leaved weeds.

All the weed control treatments significantly reduced the density and dry weight of weeds as compared to weedy check at all stages of observations (Table 1). Singh and Paikra (2014) recorded that weed control treatment caused significant reductionin total weed density and weed dry matter compared to untreated control. Venugopalan *et al.* (2012) reported that the cotton yield was directly related to increasing density weed and it's duration of interference. The results (table 1) revealed that application of pendimethalin 30 EC @ 1.0 kg a.i. ha^{-1} (PE) followed by pyrithiobac sodium 10EC @ 62.5 g a.i. ha^{-1} + quizalofop ethyl 5 EC @ 50 g a.i. ha^{-1} at 25 DAS + one hoeing at 45 DAS (T_6) recorded the lowest weed density with correspondingly lowest weed dry weight at 30 and 60 DAS which ultimately resulted into the least total weed dry weight (258.46kg ha^{-1}) which being significantly lower than rest of treatments. The significant reduction in total weed dry weight might be due to reduced numbers of weeds available due to the influence of the sequential use of PE and POE herbicides. It indicates that sequential application of PE and POE herbicides supplemented with one hoeing at 45 DAS was superior to other treatments combinations. Similar results were reported by Hiremath *et al.* (2013). Independent use of PE or POE herbicides however failed to reduce the weed count and weed dry weight in comparison to the sequential and combined use of herbicides with hoeing. This might be due to the fact that initial flush of weeds could not emerged due to effect of pendimethalin (PE) while subsequent flush of weeds were controlled by the combined spray of grassy herbicide (Quazalofop ethyl) and board leaf herbicide (Pyrithiobac sodium) at 25 DAS and the weed emerged later on were removed by hand hoeing at 45 DAS. Thus, the crop under this treatment faced the least weed competition right from germination till maturity that also relates to best use of resources as reflected in terms of seed cotton yield.

Application of pendimethalin, quizalofop ethyl and pyrithiobac sodium did not injure cotton crop, however, foliar injuries were observed by directed spray of glyphosate. All the herbicides either used alone or in combination significantly influenced of plant height, number of bolls plant^{-1}, boll weight and seed cotton yield (Table 2). Sequential application of PE + POE herbicides with one hoeing (T_6) kept the weeds under control and favoured to plant height (168cm) against 112cm observed under weedy check. Increased plant height under this treatment might be due to efficient utilization of moisture, nutrients and sunshine by cotton crop with proper aeration in the root zone, which enabled crop plants to explore their maximum potential in the presence of very less competition offered by weeds. Similar results were reported by Nalayini and Kandasamy (2013).

Maximum number of bolls (75.67 plant^{-1}) were observed in treatment having sequential use of pendimethalin (PE) followed by quizalofop ethyl +pyrithiobacs sodium (POE) with one hoeing (T_6) which was found at par with weed free check (74.33 plant^{-1}) but both treatments remained significantly superior over rest of the treatments. Whereas, maximum boll weight of 5.07g boll^{-1} was recorded in weed free check (T_8) which was statistically not superior to sequential use of pendimethalin (PE) followed by quizalofop ethyl + pyrithiobac sodium (POE) +one hoeing (5.05g boll^{-1}) or the combined spray of quizalofop ethyl + pyrithiobac sodium + one hoeing (4.95 g boll^{-1}). The increased numbers of boll plant^{-1} with bigger boll size were observed under sequential and/or combined

use of PE and POE herbicides which might be due to lesser weed competition in this treatment which in turn might have allowed crop plants to grow better with proper utilization of available resources without competition by weeds. Similarly, results were observed by Madhu *et al.* (2014).

Seed cotton yield differed significantly due to weed control treatments. The highest seed cotton yield (4630kg ha^{-1}) was obtained in weed free plot (T_8) which was statistically at par with the treatment having sequential use of PE + POE herbicides with one hoeing (4389kg ha^{-1}). The seed cotton yield obtained under this treatment (T_6) however, was significantly superior over rest of weed management treatments including weedy check, having the lowest seed cotton yield of 1304 kg ha^{-1} with yield reduction of 72 and 70% over T_8 and T_6 , respectively. The increased seed cotton yield in sequential use of PE and POE herbicides coupled with hand hoeing at 45 DAS can be attributed to reduced number of weeds during initial stage under influence of application of pendimethalin (PE)while subsequent weed flushes were controlled by combined use of pyrithiobac sodium (broad leaf control herbicide) and quizalofop ethyl (grassy weed control herbicide) at 25 DAS followed by hand hoeing at 45 DAS. In fact, the use of PE and POE herbicides coupled with hand hoeing at 45 DAS could maintain minimum level of weed competition with crop throughout the critical growing period of the crop which resulted into increased seed cotton yield owing to increased number of bolls with higher boll weight. The effective weed control in time (T_6) might have left the soil with higher amount of nutrients, soil moisture with better root aeration for crop plants to result into increased growth, yield attributes and yield of Bt cotton.Similar results were also reported by Hiremath *et al.* (2013) who showed that sequential application of PE and POE herbicide followed by intercultural operation increased 82% seed cotton yield over weedy check. Rajendra and Jain (2004) reported that the cotton yield was reduced up to 80 % in weedy check plot in Bt cotton because of reduced number of harvested bolls, boll weight and seed cotton yield per plant. Srinivasarao *et al.* (2014) reported that weeds remove 5-6 times more nitrogen, 5-12 time more phosphorous and 2-5 times more potassium than a beverage crop in the early stages of crop growth leading to low tea yield.

The data on economic analysis presented in Table 3 revealed that the maximum gross return of Rs 1, 85,185 ha^{-1} was calculated when the crop was kept free from weeds (T_8). The sequential applications of pendimethalin (PE) + quizalofop ethyl + pyrithiobac sodium (POE) + one hand hoeing at 45 DAS calculated gross returns of Rs 1,75,568 ha^{-1} which was significantly superior over rest of the treatments. Whereas, minimum gross return Rs 52,148ha^{-1} was recorded in weedy check (T_9). Similarly, the highest net returns of Rs. 1, 47,985 ha^{-1} was recorded in the weed free plot which was compared at par with T_6 (Rs 1, 44,975 ha^{-1}) which being significantly superior over rest of the treatments. However, the highest returns on per rupee spent (B: C ratio) of 4. 74 was calculated in sequential use of pendimethalin(PE) followed by quizalofop ethyl + pyrithiobac sodium (POE) with one hand weeding at 45 DAS (T_6) followed by T_5(4.54) both being significantly superior over rest of the treatments. The weed free plot (T_8) however, calculated reduced B:C ratio of 3.98 compared to T_6.The higher B: C ratio calculated in T_6 and T_5 as compared to other treatments might be due to increased seed cotton yield due to least weed competition throughout growing season under the influence of sequential use of PE and POE herbicides with one inter-culture operation with lesser cost of cultivation. The similar results were reported by Prabhu *et al.* (2012) and Hiremath *et al.* (2013).

Based on the experimental findings, the effective method of weed control with higher economic return in Bt cotton can be achieved by sequential use of pendimethalin 30 EC @1.0 kg a.i. ha^{-1} (PE) followed by combined spray of quizalofop ethyl 5 EC @ 50g a.i. ha^{-1} + pyrithiobac sodium 10 EC @ 62.5 g a.i. ha^{-1} (POE) at 25 DAS with one hand hoeing at 45 DAS without any phytotoxicity to cotton during *kharif* season.

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