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Short communication

Integrated weed management in *Bt* cotton

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Cotton is one of the major commercial crop and also called 'White Gold'. Of many problems faced by the cotton growers, the most troublesome one is the control of weeds particularly during early stages of crop growth. Venugopalan *et al*. (2009) reported a reduction in yield due to weeds in cotton crop to the extent of 50 to 85%. Farmers are facing problem of timely weed management in cotton crop and also increased cost of production due to scarcity of labours, increased labour wages *etc*. To overcome these problems farmers are using the herbicides which are available in market, without considering the lable claim of herbicides, its safe dose of application, persistency, phyto-toxicity and other technical details, which many leads creating problem to other crop or succeeding crop, adverse effect on soil micro flora and fauna, and environmental pollution.

Weeds in cotton field can be effectively killed or their growth can be minimised at the germination stage itself by the use of suitable herbicide. They are capable of giving the crop a relatively better weed free situation in the early stage of crop. Pre-emergence use of pendimethalin and oxyflurofen will control the weeds in early stages and thereby ensure efficient utilization of inputs put in by the farmers. The weeds (annual and perennial), which appear in the later period of crop growth could be controlled by combining cultural methods and post-emergence application of herbicides like quizalofop-ethyl and pyrithiobac-sodium. Thus, herbicides would solve the weed problem quite efficiently and economically. The present investigation aimed at identifying suitable integrated weed management in *Bt* cotton was conducted during *Kharif* 2014 at Post Graduate Instruction Farms, MPKV, Rahuri.

The experiment was conducted at Post Graduate Institute Farm, Mahatma Phule Krishi Vidyapeeth, Rahuri, Dist. Ahmednagar (Maharashtra) during *Kharif* season, 2014. The experiment was laid out in randomized block design consisted of three replications of ten treatments, *viz*. one hoeing at 15 days after seeding (DAS) + two hands weeding (HW) at 30 and 45 DAS, three inter cultivations with mechanical weeder at 20, 40 and 60 DAS, pendimethalin pre-emergence application (PE) at 1.0 kg/ha followed by (*fb*) one HW at 45 DAS, oxyfluorfen PE at 0.1 kg/ha *fb* one HW at 45 DAS, pendimethalin PE 1.0 kg/ha *fb* pyrithiobac-sodium post emergence application (PoE) at 75 g/ha at 45 DAS + one inter cultivation through mechanical weeder at 60 DAS, pendimethalin PE at 1.0 kg/ha *fb* quizalofop-ethyl PoE at 50 g/ha at 45 DAS + one inter cultivation through mechanical weeder at 60 DAS, oxyfluorfen PE at 0.1 kg/ha *fb* pyrathiobac-sodium PoE at 75 g/ha at 45 DAS + one inter cultivation through mechanical weeder at 60 DAS, oxyfluorfen PE at 0.1 kg/ha *fb* quizalofop-ethyl PoE at 50 g/ha at 45 DAS + one inter cultivation through mechanical weeder at 60 DAS, weedy check and weed free check. The *Bt* cotton cultivar '*Malika (NCH-207)*' was sown. The gross and net plot size were 6.3 x 5.4 m and 4.5 x 3.6 m, respectively. The soil of experimental site was clayey in texture. The soil was low in available nitrogen (194 kg/ha), phosphorous (17.45 kg/ha) and very high in potassium (483 kg/ha), soil pH 8.15 and electrical conductivity (0.23 dS/m). The recommended fertilizer dose (125:65:65 N, P_2O_5 and K_2O kg/ha) was applied through urea and single super phosphate as half of nitrogen and full of phosphorous and potassium at the time of sowing and half of nitrogen at 30 DAS. Along with the growth and yield parameters of cotton crop, total weed density, weed biomass were periodically recorded by following standard methodology, weed control efficiency, weed index, weed persistence index herbicide efficiency index and crop resistance index were calculated by using standard formulae. The pre-emergence herbicides, *viz*. pendimethalin and oxyflurofen were sprayed very next two DAS and post-emergence herbicide, *viz.* pyrathiobac-sodium and quizalofop-ethyl were applied 45 DAS as per treatments by using hand operated knapsack sprayer, fitted with flat fan nozzle.

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Weed density

The significantly lowest weed density was recorded with pendimethalin PE 1.0 kg/ha *fb* pyrathiobac-sodium PoE 75 g/ha at 45 DAS + one inter culturing with mechanical weeder at 60 DAS, oxyfluorfen PE 0.1 kg/ha *fb* pyrithiobac-sodium PoE 75 g/ha at 45 DAS + one inter culturing with mechanical weeder at 60 DAS and one hoeing at 15 DAS + two hand weeding at 30 and 45 DAS, which were at par with weed free.

The pendimethalin or oxyflurofen, PE herbicides component of integrated weed management, might have effectively hindered the germination of weed seeds in initial stage and reduced the weed dynamics of grasses, sedges and broad-leaved weeds effectively. PoE of pyrithiobac-sodium at 45 DAS might have taken care in controlling most of the later germinated broad-leaved weed species effectively and supplemented with one hoeing through mechanical weeder resulted in significantly lowering the weed density. These results were in close conformity with the results of Giri *et al.* (2006), Kaleem *et al.* (2006) and Mahar *et al.* (2007).

Weed biomass

The treatment weed free check registered significantly lowest weed biomass over the rest of treatments but it was at par with pendimethalin PE 1.0 kg/ha *fb* pyrithiobac-sodium PoE 75 g/ha at 45 DAS + one inter culturing through mechanical weeder 60 DAS, oxyfluorfen PE 0.1 kg/ha *fb* pyrithiobac-sodium PoE 75 g/ha at 45 DAS + one interculturing through mechanical weeder at 60 DAS and one hoeing at 15 DAS + two hand weeding at 30 and 45 DAS. The integrated effect of PE and PoE application of herbicides as well as hoeing through mechanical weeder resulted in keeping weed density and biomass below the critical level of competition. These results were in agreement with those reported by Panwar *et al.* (1999) and Patel *et al.* (2013).

Weed control efficiency

The significantly higher weed control efficiency was recorded in weed free check treatment (100%). This was followed by pendimethalin PE 1.0 kg/ha *fb* pyrithiobac-sodium PoE 75 g/ha at 45 DAS + one inter culturing through mechanical weeder 60 DAS (74.26%) , oxyfluorfen PE 0.1 kg/ha *fb* pyrathiobac-sodium PoE 75 g/ha at 45 DAS + one inter culturing through mechanical weeder at 60 DAS (71.07%) and one hoeing at 15 DAS + two hand weeding at 30 and 45 DAS (69.63%) at harvest. Pendimethalin or oxyflurofen PE and pyrithiobac-sodium PoE might have effectively reduced the weed density resulting in high weed control efficiency, this could be explained based on the fact that, maximum uptake and better assimilation of herbicides was pronounced as soon as weeds emerged. Less weed intensity and its lower biomass in integrated weed control treatments and mechanical weed control treatment compared to weedy check resulted in higher WCE with these treatments. The results were close conformity with the findings of Hiremath *et al.* (2013).

Weed index

Among the weed control treatments, application of pendimethalin PE 1.0 kg/ha *fb* pyrathiobac-sodium PoE 75 g/ha at 45 DAS + one inter culturing through mechanical weeder 60 DAS (5.23%), oxyfluorfen PE 0.1 kg/ha *fb* pyrathiobac-sodium PoE 75 g/ha at 45 DAS + one inter culturing through mechanical weeder at 60 DAS (5.65%) and one hoeing at 15 DAS + two hand weeding at 30 and 45 DAS (5.95%), recorded significantly minimum weed index as compared to rest of the treatments. The significantly maximum weed index (62.84%) was noticed in weedy check treatments. Lower weed index was due to higher *Bt* seed cotton yield in the corresponding treatments and vice versa. This might be due to sequential herbicidal application with one supplemented hoeing through mechanical weeder. The results were close conformity with the findings of Hiremath *et al.* (2013).

Herbicide efficiency index

The data revealed that, numerically maximum value of herbicide efficiency index was rest with application of pendimethalin PE 1.0 kg/ha *fb* pyrithiobac-sodium PoE 75 g/ha at 45 DAS + one inter culturing through mechanical weeder 60 DAS (4.40%) but it was at par with oxyfluorfen PE 0.1 kg/ha *fb* pyrithiobac-sodium PoE 75 g/ha at 45 DAS + one inter culturing through mechanical weeder at 60 DAS (3.52%). This data reveals that PE and PoE herbicides application was effective along with integrated management as compared to application of pre-emergence herbicide alone.

Weed persistence index

Among the weed control treatments, significantly minimum weed persistence index value was observed at harvest with treatment PE application of application of pendimethalin PE 1.0 kg/ha *fb* pyrithiobac-sodium PoE 75 g/ha at 45 DAS + one inter culturing through mechanical weeder 60 DAS, (1.38%) but it was at par with oxyfluorfen PE 0.1 kg/ha *fb* pyrithiobac-sodium PoE 75 g/ha at 45

DAS + one inter culturing through mechanical weeder at 60 DAS (1.42%), and one hoeing at 15 DAS + two hand weeding at 30 and 45 DAS, (1.44%).

Crop resistance index

Among the weed control treatments, crop resistance index at harvest significantly maximum with PE application of application of pendimethalin PE 1.0 kg/ha *fb* pyrithiobac-sodium PoE 75 g/ha at 45 DAS + one inter culturing through mechanical weeder at 60 DAS (6.41), but it was at par with oxyfluorfen PE 0.1 kg/ha *fb* pyrithiobac-sodium PoE 75 g/ha at 45 DAS + one inter culturing through mechanical weeder at 60 DAS (4.67) and one hoeing at 15 DAS + two hand weeding at 30 and 45 DAS, (4.52).

Seed cotton yield

The seed cotton yield under weed free check treatment (2.72 t/ha) was significantly higher than rest of treatments. However, it was at par with pendimethalin PE 1.0 kg/ha *fb* pyrithiobac-sodium PoE 75 g/ha at 45 DAS + one inter culturing through mechanical weeder 60 DAS (2.58 t/ha), oxyfluorfen PE 0.1 kg/ha *fb* pyrithiobac-sodium PoE 75 g/ha at 45 DAS + one inter culturing through mechanical weeder at 60 DAS (2.56 t/ha) and one hoeing at 15 DAS + two hand weeding at 30 and 45 DAS (2.56 t/ha). This might be due to low weedy situation during initial stage and further control of latter germinated of weeds by application of post-emergence herbicides at 45 DAS with supplemented inter cultivation through mechanical weeder at 60 DAS and thus, reducing the weed competition during critical initial to peak growth period of the crop. In fact, inter cultivation operation carried out at 60 DAS almost maintained weed free condition throughout remaining period of crop growth period. These results were in conformity with those reported by Hiremath *et al.* (2013).

Lint yield

The lint yield was significantly higher in weed free check (980 kg/ha) than rest of treatments. However, it was at par with pendimethalin PE 1.0 kg/ha *fb* pyrithiobac-sodium PoE 75 g/ha at 45 DAS + one interculturing through mechanical weeder at 60 DAS (945 kg/ha), oxyfluorfen PE 0.1 kg/ha *fb* pyrithiobac-sodium PoE 75 g/ha at 45 DAS + one interculturing through mechanical weeder at 60 DAS (933 kg/ha) and one hoeing at 15 DAS + two hand weeding at 30 and 45 DAS (922 kg/ha). This might due to higher accumulation of photosynthates in leaves, stem and reproduction parts, resulted in better development of bolls and thereby increase lint yield in integrated weed control and weed free treatments. Similar results were reported by Hiremath *et al.* (2013).

Stalk yield

The stalk yield under weed free check treatment (4.08 t/ha) was significantly higher than rest of treatments except pendimethalin PE 1.0 kg/ha *fb* pyrithiobac-sodium PoE 75 g/ha at 45 DAS + one

Table 1. Effect of different weed control treatments on weed dynamics in *Bt.* cotton

Treatment	Weed density (no./m^2)			Weed biomass (g/m^2)	WCE (%)	Weed index	Herbicide efficiency index	Crop resistance index	Weed persistence index
	20 DAS	60 DAS	At Harvest						
One hoeing at 15 DAS + two hand weeding at 30 and 45 DAS	4.4(19.1)	5.1(25.5)	8.0(63.5)	8.2(67.4)	69.63	5.95	-	4.52	1.44
Three inter culturing through mechanical weeder at 20, 40 and 60 DAS	5.6(30.7)	6.1(37.1)	8.6(73.3)	8.7(75.7)	64.94	43.28	-	3.46	1.56
Pendimethalin PE 1.0 kg/ha *fb* one HW at 45 DAS	5.0(24.6)	5.3(27.6)	8.6(74.0)	8.3(69.2)	64.62	30.87	1.71	4.20	1.47
Oxyfluorfen PE 0.1 kg/ha *fb* one HW at 45 DAS	5.5(29.9)	5.4(29.1)	8.8(76.8)	8.7(70.3)	63.27	34.14	1.67	4.05	1.61
Pendimethalin PE 1.0 kg/ha *fb* pyrithiobac-sodium PoE 75 g/ha at 45 DAS + one interculturing through mechanical weeder at 60 DAS	4.1(16.3)	5.1(25.8)	7.4(53.8)	7.2(52.2)	74.26	5.23	4.40	6.41	1.38
Pendimethalin PE 1.0 kg/ha *fb* quizalofop-ethyl PoE 50 g/ha at 45 DAS + one interculturing through mechanical weeder at 60 DAS.	5.1(25.9)	6.0(36.0)	8.1(65.9)	8.5(71.2)	68.47	40.05	1.38	4.01	1.60
Oxyfluorfen PE 0.1 kg/ha *fb* pyrithiobac-sodium PoE 75 g/ha at 45 DAS + one interculturing through mechanical weeder at 60 DAS	4.3(17.8)	4.4(18.9)	7.8(60.5)	8.0(64.1)	71.07	5.65	3.52	4.67	1.42
Oxyfluorfen PE 0.1 kg/ha *fb* quizalofop-ethyl PoE 50 g/ha at 45 DAS + one interculturing through mechanical weeder at 60 DAS	5.9(34.5)	6.1(36.8)	8.4(70.9)	8.6(73.7)	66.09	42.88	1.06	3.65	1.55
Weedy check	9.0(80.9)	11.9(140.9)	14.5(209.1)	11.7(137.0)	0.00	62.84	0.00	1.00	100
Weed free check	0.00	0.00	00	0.00	100.00	0.00	-	0.00	0.00
LSD (p=0.05)	0.54	0.76	0.70	0.98	1.62	0.37	0.18	0.29	0.06

$\sqrt{x+0.5}$ Transformed values. Original values are in parentheses; HW-Hand weeding; DAS-Days after sowing; *fb*- Followed by; PE-Pre-emergence; PoE - Post-emergence

Table 2. Effect of weed control treatments on plant growth attributes, yield attributes, seed cotton, lint, stalk yield and economics of *Bt*. cotton

Treatment	Seed cotton yield (t/ha)	Lint yield (kg/ha)	Stalk yield (t/ha)	Cost of cultivation (x10^3 `/ha)	Net returns (x10^3 `/ha)	B : C Ratio
One hoeing at 15 DAS + two hand weeding at 30 and 45 DAS	2.56	922	3.84	54.32	54.01	1.99
Three inter culturing through mechanical weeder at 20, 40 and 60 DAS	1..3	531	2.30	40.39	24.47	1.60
Pendimethalin PE 1.0 kg/ha *fb* one HW at 45 DAS	1.86	651	2.79	46.82	31.89	1.68
Oxyfluorfen PE 0.1 kg/ha *fb* one HW at 45 DAS	1.78	628	2.67	45.68	29.61	1.64
Pendimethalin PE 1.0 kg/ha *fb* pyrithiobac-sodium PoE 75 g/ha at 45 DAS + one interculturing through mechanical weeder at 60 DAS	2.58	945	3.87	42.27	66.70	2.57
Pendimethalin PE 1.0 kg/ha *fb* quizalofop-ethyl PoE 50 g/ha at 45 DAS + one interculturing through mechanical weeder at 60 DAS.	1.63	570	2.45	40.79	28.16	1.69
Oxyfluorfen PE 0.1 kg/ha *fb* pyrithiobac-sodium PoE 75 g/ha at 45 DAS + one interculturing through mechanical weeder at 60 DAS	2.56	933	3.84	41.13	67.24	2.63
Oxyfluorfen PE 0.1 kg/ha *fb* quizalofop-ethyl PoE 50 g/ha at 45 DAS + one interculturing through mechanical weeder at 60 DAS	1.55	546	2.32	40.90	24.55	1.60
Weedy check	1.00	353	1.51	36.64	5.86	1.15
Weed free check	2.72	980	4.08	55.84	59.21	2.06
LSD (p=0.05)	0.17	64	0.54		13.92	

HW-Hand weeding; DAS-Days after sowing; *fb*- Followed by; PE- Pre-emergence; PoE - Post-emergence

interculturing through mechanical weeder at 60 DAS (3.87 t/ha), oxyfluorfen PE 0.1 kg/ha *fb* pyrithiobac-sodium PoE 75 g/ha at 45 DAS + one interculturing through mechanical weeder at 60 DAS (3.84 t/ha) and one hoeing at 15 DAS + two hand weeding at 30 and 45 DAS (3.84 t/ha). This might due to higher accumulation of photosynthates in leaves, stem and reproduction parts. Similar result were reported by Hiremath *et al.* (2013).

Economics

Significantly the highest net returns (` 67239/ ha) with maximum B:C ratio (2.63) was accrued with oxyfluorfen PE 0.1 kg/ha *fb* pyrithiobac-sodium PoE 75 g/ha at 45 DAS + one inter culturing through mechanical weeder at 60 DAS compared to rest of the treatments, but was found at par with pendimethalin 1.0 kg/ha PE *fb* pyrathiobac sodium PoE 75 g/ha at 45 DAS + one interculturing through mechanical weeder 60 DAS which recorded next best net returns (` 66696/ha) and B:C ratio (2.57). The highest net returns and maximum B:C value was observed with oxyfluorfen PE 0.1 kg/ha *fb* pyrathiobac-sodium PoE 75 g/ha at 45 DAS + one inter culturing through mechanical weeder at 60 DAS and pendimethalin PE 1.0 kg/ha *fb* pyrathiobac-sodium PoE 75 g/ha at 45 DAS + one inter culturing through mechanical weeder at 60 DAS might be due to higher gross returns and comparatively less cost of production compared to treatment Weed free check and one hoeing at 15 DAS + two hand weeding at 30 and 45 DAS. These results were in conformity with those reported by Hiremath *et al.* (2013).

SUMMARY

Application of pendimethalin PE 1.0 kg/ha or oxyfluorfen PE 0.1 kg/ha *fb* pyrithiobac-sodium PoE 75 g/ha at 45 DAS + one inter culturing through mechanical weeder 60 DAS in *Bt*. cotton recorded significantly lowest total weed density, weed biomass, weed index and weed persistence index while higher WCE, herbicide efficiency index, crop resistance index also higher seed cotton, lint, stalk yield, net returns and B:C ratio.

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