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Economic viability of sequential application of pre and post emergence herbicides in *Bt* cotton

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ABSTRACT: A field experiment was conducted during *kharif,* 2012-2013 to study the effect of sequential application of pre emergence herbicides fb post emergence herbicidies on nutrient uptake by crop and weed and to evaluate the best economical sequential application of herbicides in cotton. Among herbicidal treatments, pre emergence application of diuron @ 1.25 kg a.i./ha fb post-emergence application of glyphosate @ 2.5 kg a.i./ha (T_{10}) and pre emergence application of diuron @ 1.25 kg a.i./ha fb post emergence application of glufosinate ammonium @ 0.375 kg a.i./ha (T_{11}) recorded significantly lower weed density and dry weight of weeds. Whereas the same treatments showed significantly higher number of harvested bolls/plant, boll weight, seed cotton yield, and net returns.

Key words : *Bt* cotton, growth, herbicides, return, weed, yield,

Cotton is one of the main cash crops in our country particularly in Vidarbha region of Maharashtra state. Due to its slow initial growth coupled with wider spacing, adequate fertilization and frequent rains, the crop is most vulnerable to weed infestation. The weeds compete with the crop for the nutrients, moisture, space and light, thus affecting the growth and development of crop during early stages of growth. Weeds consume 5 to 6 times nitrogen, 5 to 12 times phosphorus and 2 to 5 times potash more than cotton crop at the early growth stages and thus reduce seed cotton yield from 54 to 85 per cent. Pre emergence herbicides like diuron and pendimethalin are effective to give initial weed control upto 30-40 days but the crop being a long duration one, the late emerging weeds need to be controlled by hoeing and hand weeding. Manual weeding has traditionally been a labor intensive operation and hence there is no other alternative rather than use of post emergence herbicides for control of weeds in cotton. Herbicide is an economic alternative when labor is a problem or in abnormal weather situation where fields are not accessible for mechanical weeding. Chemical weed control becomes more important and attractive to farmers. To be effective, however, herbicides need to be matched with the weed problem. Successful weed control is essential for economic cotton production.

Field investigations were carried out at University of Agricultural Sciences, Dharwad, during *kharif*, 2012-2013. Field trial was laid out in randomized block design with 14 treatments replicated thrice. Treatments in the present study consisted of per-emergence application of diuron (1.25 kg/ha) which was sprayed within 24 h of sowing and post emergence application of imezathapyr (75 g/ha), pyrithiobac (75 g/ha) as blanket spray, oxyfluorfen (0.10 kg/ha), glyphosate (2.5 kg/ha) and glufosinate ammonium (375 g/ha) as directed spray at 35 and 55 Days After Sowing (DAS) were compared with farmers practice, weed free and weedy check. The soil of the experimental site was black clay loam in texture with low in available nitrogen content (223.65 kg N/ha) and medium in available phosphorous (31.32 kg P_2O_5/ha) and high in available potassium (332.42 kg K_2O/ha). *Bt* cotton hybrid NCS-145 (Bunny *Bt* II) was sown at 90 cm x 60 cm spacing. The crop was fertilized with 80:40:40 NPK kg/ha. The observation on plant and

yield attributes were recorded from five tagged plants selected randomly. Weed observation was recorded in one m^2 area from each plot.

Diuron, pre emergence herbicide was sprayed uniformly very next day after sowing as per treatments and post emergence herbicides *viz.*, imezathapyr, oxyfluorfen, pyrithiobac, glyphosate, glufosinate ammonium were applied uniformly at 35 and 55 DAS as per the treatments with 750 liters of spray solution with knapsack sprayer.

Observations on total weed density, total weed dry weight, plant height, leaf area index, boll weight, seed cotton yield/plant and seed cotton yield were taken.

Weed Flora : The weed infestation in the experimental plot during the period of experimentation was predominantly consisted of grassy weeds, sedges and broad leaved weeds. Among broad leaved weeds, *Ageratum conyzoides, Alternanthera sessilis, Commelina benghalensis*, *Euphorbia geniculata, Mollugo disticha, Parthenium hysterophorus, Phylanthus maderaspatensis*, *Corchorus trilocularis*; among the grassy weeds, *Brachiaria eruciformis, Cynodon dactylon, Dinebra retroflexa* and among sedges, *Cyperus rotundus*.

Effect on weeds : In general, the density and dry weight of weeds were significantly reduced with the application of herbicides compared to weedy check. Weed free check (T_{12}) and weedy check (T_{13}) recorded significantly lower and higher weed density per m^2 and total dry weight respectively (Table 1). Among the herbicidal treatment least weed density/m^2 and total dry weight of weeds was recorded under pre emergence application of diuron @ 1.25 kg a.i./ha fb post-emergence application of glyphosate @ 2.5 kg a.i./ha (T_{10}) (1.94 and 1.33 g/m^{-2} respectively), which was *on par* with pre emergence application of diuron @ 1.25 kg a.i./ha fb post-emergence application of glufosinate ammonium @ 0.375 kg a.i./ha (T_{11}) (2.33 and 1.44 g/m^{-2}) to rest of the treatments at 60 DAS, compared to individual application of herbicides. The same trend was followed at 90 and 120 DAS. 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 followed by control of all type of weeds by spraying the directed application of glyphosate and glufosinate ammonium 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).

Effect on yield and yield components : Significant increase in number of harvested bolls/plant, boll weight, seed cotton yield per plant and seed cotton yield were observed due to different weed management practices (Table 2). Number of harvested bolls, boll weight, seed cotton yield/plant and seed cotton yield were higher in weed free check and least in weedy check. Among different herbicidal treatments, number of harvested bolls (48.93), boll weight (5.15 g), seed cotton yield/plant (124.99 g) and seed cotton yield (2314.40 kg/ha) were significantly higher with pre emergence application of diuron @ 1.25 kg a.i./ha fb post emergence application of glyphosate @ 2.5 kg a.i./ha (T_{10}) compared to farmers practice or individual application of herbicides and it was *on par* with pre emergence application of diuron @ 1.25 kg a.i./ha fb post emergence application of glufosinate ammonium @ 0.375 kg a.i./ha (T_{11}). The superior performance of these treatments was mainly due to effective control of weeds and minimum dry weight of weeds due to sequential application of herbicides. Various research workers have also reported effective control of weeds when herbicides were used in sequence (Singh *et al.*, 2004 and Prabhu *et al.*, 2012).

Table 1. weed density/m^2 and total dry weight of weeds (g m^2) as influenced by different weed management practices

Treatments	Total number of weeds/m^2 (DAS)			Total dry weight of weeds (g/m) (DAS)		
	60	90	120	60	90	120
T_1 Diuron 1.25 kg a.i./ha (PRE)	4.87 (23.33)	5.43 (29.00)	5.58 (30.67)	3.16 (9.51)	5.74 (32.69)	6.16 (37.51)
T_2 Imezathapyr 0.075 kg a.i./ha (POST at 30-40 DAS)	5.30 (27.67)	6.82 (46.00)	7.15 (50.67)	4.55 (20.22)	6.61 (43.19)	7.01 (48.68)
T_3 Oxyfluorfen 0.1 kg a.i./ha (POST at 30-40 DAS)**	4.87 (23.33)	6.38 (40.33)	6.52 (42.00)	3.82 (14.25)	6.03 (36.04)	6.67 (44.12)
T_4 Pyrithiobac 0.075 Kg a.i./ha (POST at 30-40 DAS)	6.33 (39.67)	7.22 (51.67)	7.42 (54.67)	5.03 (24.89)	7.01 (48.63)	7.38 (54.04)
T_5 Glyphosate 2.5 kg a.i./ha^- (POST at 30-40 DAS) **	4.62 (21.00)	5.04 (25.00)	5.33 (28.00)	2.98 (8.47)	5.46 (29.40)	5.57 (30.57)
T_6 Glufosinate ammonium 0.375 kg a.i./ha (POST at 30-40 DAS)**	5.07 (25.33)	6.38 (40.33)	6.63 (43.67)	3.99 (15.44)	6.31 (39.50)	6.84 (46.33)
T_7 Diuron 1.25 kg a.i./ha (PRE) fb Imezathapyr 0.075 kg a.i./ha (POST at 50-60 DAS)	3.80 (14.00)	4.66 (21.33)	5.01 (24.67)	2.22 (4.46)	5.29 (27.55)	5.41 (28.74)
T_8 Diuron 1.25 kg a.i./ha (PRE) fb Oxyfluorfen 0.1 kg a.i./ha (POST at 50-60 DAS)**	2.79 (7.33)	3.72 (13.33)	4.19 (17.33)	1.93 (3.27)	4.66 (21.29)	4.78 (22.38)
T_9 Diuron 1.25 kg a.i./ha (PRE) fb Pyrithiobac 0.075 kg a.i./ha (POST at 50-60 DAS)	3.24 (10.00)	4.17 (17.00)	4.74 (22.00)	2.15 (4.12)	4.73 (21.94)	4.78 (22.42)
T_{10}Diuron 1.25 kg a.i./ha (PRE) fb Glyphosate 2.5 kg a.i./ha (POST at 50-60 DAS)**	1.94 (3.33)	2.29 (5.00)	2.73 (7.00)	1.33 (1.28)	2.54 (6.01)	2.74 (7.09)
T_{11}Diuron 1.25 kg a.i./ha (PRE) fb Glufosinate ammonium 0.375 kg a.i./ha (POST at 50-60 DAS)**	2.23 (5.00)	2.67 (6.67)	2.89 (8.00)	1.44 (1.60)	2.73 (7.12)	3.05 (8.91)
T_{12}Weed free check	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)
T_{13}Weedy check	11.02 (121)	11.51 (132.0)	11.05 (121.67)	7.85 (61.20)	10.49 (110.03)	10.80 (116.26)
T_{14} Farmers practice (IC fb HW at 30 and 60 DAS)	5.46 (29.33)	4.18 (17.00)	4.70 (21.67)	2.90 (7.93)	4.65 (21.10)	4.68(21.44)
S.Em.±	0.22	0.21	0.22	0.14	0.23	0.18
CD (p = 0.05)	0.64	0.60	0.64	0.40	0.67	0.53

DAS= Days after sowing, PRE=Pre emergence, POST=Post emergence, fb= followed by, IC= Intercultivation, HW= Hand weeding

* Figures indicating (Öx+0.5) transformed values, Figures in parenthesis are indicating original values, ** Indicating directed spray

Table 2. Number of bolls harvested/plant, boll weight (g), seed cotton yield/plant (g), seed cotton yield (kg/ha) as influenced by different weed management practices

Treatments	Harvested bolls/ plant	Boll weight (g)	Seed cotton yield/ plant (g)	Seed cotton yield (kg/ha)
T_1 Diuron 1.25 kg a.i./ha (PRE)	34.93	3.64	89.48	1657.4
T_2 Imezathapyr 0.075 kg a.i./ha (POST at 30-40 DAS)	26.67	2.71	68.59	1264.0
T_3 Oxyfluorfen 0.1 kg a.i./ha (POST at 30-40 DAS)**	33.13	3.48	82.02	1556.8
T_4 Pyrithiobac 0.075 Kg a.i./ha (POST at 30-40 DAS)	21.73	2.22	54.30	1011.7
T_5 Glyphosate 2.5 kg a.i./ha (POST at 30-40 DAS)**	38.27	3.91	97.99	1812.4
T_6 Glufosinate ammonium 0.375 kg a.i./ha (POST at 30-40 DAS)**	30.00	3.12	75.84	1423.1
T_7 Diuron 1.25 kg a.i./ha (PRE) fb Imezathapyr 0.075 kg a.i./ha (POST at 50-60 DAS)	39.60	4.08	100.48	1860.7
T_8 Diuron 1.25 kg a.i./ha (PRE) fb Oxyfluorfen 0.1 kg a.i./ha (POST at 50-60 DAS)**	43.67	4.57	111.80	2035.4
T_9 Diuron 1.25 kg a.i./ha (PRE) fb Pyrithiobac 0.075 kg a.i./ha (POST at 50-60 DAS)	41.93	4.31	104.57	1997.5
T_{10}Diuron 1.25 kg a.i./ha (PRE) fb Glyphosate 2.5 kg a.i./ha (POST at 50-60 DAS)**	48.93	5.15	124.99	2314.4
T_{11}Diuron 1.25 kg a.i./ha (PRE) fb Glufosinate ammonium 0.375 kg a.i./ha (POST at 50-60 DAS)**	48.80	5.10	125.08	2310.1
T_{12}Weed free check	49.80	5.20	128.97	2369.8
T_{13}Weedy check	12.47	1.37	28.19	578.2
T_{14}Farmers practice (IC fb HW at 30 and 60 DAS)	42.53	4.40	106.67	1979.4
S.Em.±	1.82	0.20	4.68	105.9
CD (p=0.05)	5.51	0.60	14.19	321.4

DAS= Days after sowing, PRE=Pre emergence, POST=Post emergence, fb= followed by, IC= Intercultivation, HW= Hand weeding ** Indicating directed spray

Economics of weed control : The data presented in the Table 2 indicate that weed control treatments markedly affected net returns and B:C ratio. Net return was significantly higher with pre-emergence application of diuron @ 1.25 kg a.i./ha fb post emergence application of glufosinate ammonium @ 0.375 kg a.i./ha (T_{11}) (‘ 78773/ha) which was on par with pre emergence application of diuron @ 1.25 kg a.i./ ha fb post emergence application of glyphosate @ 2.5 kg a.i./ha (T_{10}) (‘ 78508/ha), weed free check (T_{12}) (‘ 76296/ha) and preemergence application of diuron @ 1.25 kg a.i./ha fb post emergence application of oxyfluorfen @ 0.1 kg a.i./ha (T_8) (‘66035/ha). Net returns were significantly lower in weedy check (‘5163/ha) compared to other treatments. The higher net returns in these treatments could be attributed to higher seed cotton yield and lower cost of cultivation. Lower net returns in weedy check was mainly due to lower seed cotton yield. Hallikeri *et al.*, (2004) and Prabhu *et al.*, (2012) also reported the similar findings.

Benefit cost ratio was significantly higher with pre emergence application of diuron @ 1.25 kg a.i./ha fb post emergence application of glufosinate ammonium @ 0.375 kg a.i./ha (T_{11}) (3.99) when compared with rest of the treatments. This was mainly due to higher economic yield, net returns and lower cost of cultivation. However, pre emergence application of diuron @1.25 kg a.i./ha fb post emergence application of glyphosate @ 2.5 kg a.i./ha (T_{10}) (3.92) recorded B: C ratio which was *on par* with T_{11}. The lower B: C ratio was recorded with post emergence application of pyrithiobac @ 0.075 kg

Table 3. Economics of Bt-cotton as influenced by different weed management practices

Treat-ments		Seed cotton yield (kg/ha)	Cost of cultivation (/ha)	Gross returns (/ha)	Net returns (/ha)	Benefit : Cost ratio
T_1	Diuron 1.25 kg a.i. /ha (PRE)	1657.4	24543	75412	50869	3.06
T_2	Imezathapyr 0.075 kg a.i. /ha (POST at 30-40 DAS)	1264.0	22897	57512	34614	2.51
T_3	Oxyfluorfen 0.1 kg a.i. /ha (POST at 30-40 DAS)**	1556.8	24378	70834	46456	2.90
T_4	Pyrithiobac 0.075 Kg a.i. /ha (POST at 30-40 DAS)	1011.7	24052	46034	21982	1.91
T_5	Glyphosate 2.5 kg a.i. /ha (POST at 30-40 DAS)**	1812.4	24553	82462	57909	3.36
T_6	Glufosinate ammonium 0.375 kg a.i. /ha (POST at 30-40 DAS)**	1423.1	23322	64749	41427	2.77
T_7	Diuron 1.25 kg a.i. /ha (PRE) fb Imezathapyr 0.075 kg a.i. /ha (POST at 50-60 DAS)	1860.7	25331	84662	59331	3.34
T_8	Diuron 1.25 kg a.i. /ha (PRE) fb Oxyfluorfen 0.1 kg a.i. /ha (POST at 50-60 DAS)**	2035.4	26575	92610	66035	3.48
T_9	Diuron 1.25 kg a.i. /ha (PRE) fb Pyrithiobac 0.075 kg a.i. /ha (POST at 50-60 DAS)	1997.5	27263	90888	63624	3.33
T_{10}	Diuron 1.25 kg a.i. /ha (PRE) fb Glyphosate 2.5 kg a.i. /ha (POST at 50-60 DAS)**	2314.4	26797	105305	78508	3.92
T_{11}	Diuron 1.25 kg a.i. /ha (PRE) fb Glufosinate ammonium 0.375 kg a.i. /ha (POST at 50-60 DAS)**	2310.1	26336	105109	78773	3.99
T_{12}	Weed free check	2369.8	31528	107824	76296	3.42
T_{13}	Weedy check	578.2	21145	26308	5163	1.24
T_{14}	Farmers practice (IC fb HW at 30 & 60 DAS)	1979.4	28022	90064	62042	3.21
	S.Em.±	105.9	-	4820	4608	0.16
	CD (p=0.05)	321.4	-	14622	13979	0.50

DAS= Days after sowing, PRE=Pre-emergence, POST=Post-emergence, fb= followed by, IC= Intercultivation, HW= Hand weeding ** Indicating directed spray

a.i./ha (T_4) (1.91) followed by weedy check (T_{13}) (1.24). Though there was higher yield and gross income in weed free check in comparison to pre emergence application of diuron @ 1.25 kg a.i./ ha fb post emergence application of glufosinate ammonium @ 0.375 kg a.i./ha (T_{11}) (3.99), the B:C ratio found lower. This was mainly due to lower gross returns and higher cost of cultivation.

Thus from the above study, it could be concluded that sequential application of herbicides is effective in controlling weeds, increased seed cotton yield and would be definitely economical in situations where labour charges are high, labour availability is uncertain during peak period and where interculture operations and hand weedings are not practicable due to unfavourable weather and soil condition.

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