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Effect of post–emergence application of cyhalofop-butyl for weed management in direct-seeded rice (*Oryza sativa*)

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Rice (*Oryza sativa* L.) is the most important staple food for more than half of the world's population. It is being cultivated by different methods considering the scarcity of water, traditional method of rice cultivation is becoming labor intensive and costlier, which encourages the rice farmer to shift from traditional to direct-seeding. However, direct-seeding of rice faces severe weed competition which may cause yield reduction up to 80% (Jabran *et al*. 2012). Direct-seeding of rice is possible and may be comparable to traditional method, if, there is good crop establishment and adequate timely weed management is done (Rao *et al*.2008, Rao and Nagamani 2007). Application of pre-emergence herbicide like butachlor and pretilachlor could not be able to control late emerging weeds in rice. In order to have complete weed management during critical crop growth, the need is felt to have sequential application of pre-emergence and post-emergence herbicide for managing all flushes of weeds that occurs at different growth stages of rice crop. So, the present investigation was undertaken to find out the appropriate combination of pre-emergence and post emergence herbicide to keep rice free from weeds.

The experiment was conducted at Indian Agricultural Research Institute, New Delhi (28^o 40'N, 77^o 11'E and 228 m above mean sea level) during *kharif* 2009-10. The soil was sandy loam with pH 7.5, organic carbon 0.50%, available P 15.40 kg/ha, and available K 245 kg/ha. The total rainfall of 504.4 mm was received in 17 rainy-days during the crop-growing season. Ten weed control treatments comprising two doses of cyhalofop-butyl (60 and 80 g/ha) each applied at 10 and 20 days after sowing (DAS), butachlor at 1 000 g/ha as pre-emergence, pretilachlor at 1 000 g/ha as pre-emergence, sequential application of pretilachlor at 750 g/ha as pre-emergence and cyhalofop-butyl at 60 g/ha as post emergence at 30 DAS, sequential application of butachlor at 750 g/ha as pre-emergence and cyhalofop butyl at 60 g/h as post emergence at 30 DAS, weed free and weedy check were laid out in randomized block design with three replication. Pre-emergence application of pretilachlor and butachlor was made a DAS whereas post-emergence application of cyhalofop-butyl was done at 10, 20 and 30 DAS as per the treatment. An uniform dose of 120 kg N/ha in the form of urea, 60 kg P_2O_5/ha through SSP and 40 kg K_2O/ha through MOP was applied. Half dose of N and full dose of P_2O_5 and K_2O was applied at the time of sowing while the remaining N was applied at 40 DAS. Rice Pusa Sugandh 5 was sown in rows at a seed rate of 40 kg/ha using kera method of sowing at row spacing of 20 cm on to non-puddle soil on 15 June 2009. Herbicides were applied with the help of knap-sack sprayer delivering a spray volume of 600 litres/ha through flat-fan nozzle. Data on weeds were recorded at 60 DAS in each plot in two quadrats, each measuring 50 cm × 50 cm. Weeds were counted species-wise and were removed for recording their dry weights. Weed sample were sun-dried before oven drying at 70°C until constant weight was attained. All the yield attributes, viz panicle/m^2, panicle length (cm), spikelet/panicle, filled grains/panicle, test weight (g) was recorded just before harvest of the crop. Grain and straw yields was also recorded after the harvest of the rice crop and then converted into tonnes/ha. Crop was manually harvested on 14 October 2009. The herbicide residue was estimated by HPLC and it was presented as HPLC chromatogram (Fig 1). The population of total heterotrophic bacteria, fungi and actinomycetes was counted using serial dilution and plating technique. Data on weeds were subjected to square root transformation before statistical analysis. The least significant difference (LSD) values were calculated at P=0.05 level of significance to test significant differences between treatment means.

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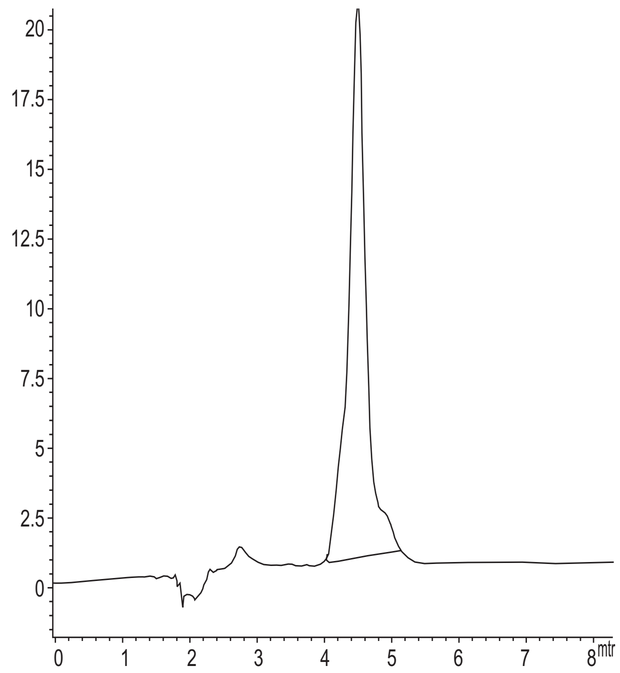

Fig 1 HPLC Chromatogram of cyhalofop-butyl herbicide

The dominant weed flora in the present experiment comprised of *Echinochloa crusgalli* (27.5%), *Leptochloa chinensis* (26.2%), *Echinochloa colona* (15.6%), *Eclipta alba* (13.3%) and *Cyperus difformis* (17.2%). The number of monocot weeds constituted the major proportion of the total weed population as well as total weed dry matter accumulation, irrespective of the dose, time of application and herbicide. Population and dry weight was significantly reduced due to herbicidal treatment at 60 DAS. This may be attributed to the inhibition of germination of weeds owing to paralysis of vital metabolic process, viz. cell division, protein synthesis etc and subsequently drying of susceptible weed species. (Singh *et al*. 1990 and Ramsak 2001). Application of cyhalofop-butyl was found to be more effective in decreasing the density and dry matter of all weeds at 20 DAS than its application at 10 DAS. This could be attributed to the optimum growth stage of weed at the time of application. Sharma *et al*. (2004) also reported the better efficacy of cyhalofop-butyl in reducing density and dry matter of *Echinochloa crus-galli* when applied at 14 DAS compared to its application at 8 DAS. At 60 DAS, the lowest weed population (7.74/m^2), dry weight (5.8 g/m^2) and the highest weed control efficiency (79.37%) were recorded with sequential application of pretilachlor (750 g/ha) and cyhalofop-butyl (60 g/ha) which was comparable with sequential application of butachlor (750 g/ha) and cyhalofop-butyl (60 g/ha) (Table 1). This may be probably due to effective control of the emerging weeds in initial stage with the pre-emergence application of pretilachlor or butachlor and of late emerged weeds by post-emergence application of cyhalofop-butyl (60 g at 30 DAS). Similar

Table 1 Effect of weed control treatment on the species wise weed density and weed control efficiency at 60 days after sowing

Treatment	Weed density at 60 DAS (No/m^2)					
	E. crusgalli	*L. chinensis*	*E. colona*	*E. alba*	*C. difformis*	Weed control efficiency (%)
Cyhalofop-butyl @ 60 g/ha at 10 DAS	7.39 (54.11)	7.72 (59.10)	5.25 (27.07)	5.36 (28.23)	5.86 (33.84)	27.96
Cyhalofop-butyl @ 80 g/ha at 10 DAS	5.82 (33.37)	6.12 (36.95)	4.26 (17.65)	4.93 (23.8)	4.87 (23.22)	51.36
Cyhalofop-butyl @ 60 g/ha at 20 DAS	5.48 (29.53)	6.43 (40.84)	4.35 (18.42)	4.58 (20.48)	5.00 (24.5)	51.79
Cyhalofop-butyl @ 80 g/ha at 20 DAS	4.85 (23.02)	5.09 (25.41)	3.60 (12.46)	4.37 (18.60)	4.41 (18.95)	64.06
Butachlor @ 1000 g/ha PE	6.95 (47.80)	6.82 (46.01)	5.00 (24.5)	3.60 (12.46)	4.68 (21.4)	45.39
Pretilachlor @ 1000 g/ha PE	6.59 (42.93)	5.98 (35.26)	4.81 (22.65)	3.39 (10.99)	4.52 (19.93)	52.49
Butachlor @ 750 g/ha PE fb cyhalofop-butyl @ 60 g/ha at 30 DAS	3.89 (14.63)	4.15 (16.72)	2.56 (6.05)	3.33 (10.59)	3.80 (13.94)	76.74
Pretilachlor @ 750 g/ha PE fb cyhalofop-butyl @60 g/ha at 30 DAS	3.60 (12.53)	4.00 (15.50)	2.50 (5.75)	3.19 (9.68)	3.38 (10.92)	79.37
Weedy check	8.85 (77.82)	8.64 (74.15)	6.68 (44.12)	6.19 (37.82)	7.03 (48.92)	0.00
Weed free	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	0.71 (0.00)	100.00
SEm ±	0.35	0.38	0.25	0.25	0.26	3.33
LSD (P=0.05)	1.04	1.13	0.76	0.76	0.79	9.97

Fb, Followed by; PE, Pre-emergence; DAS, Days after sowing. Data were subjected to $\sqrt{x+0.5}$ transformations before statistical analysis. Figure in parentheses are the original values.

finding were also reported by Rao *et al*. (2008) and Walia *et al*. (2008) and Singh *et al*. (2008).

Among the herbicidal treatments, sequential application of pretilachlor (750 g/ha) and cyhalofop-butyl (60 g/ha), sequential application of butachlor (750 g/ha) and cyhalofop-butyl (60 g/ha) and alone application of cyhalofop-butyl 80 g/ha at 20 DAS recorded significantly higher increase in yield attributes such as panicles/m^2, panicle length (cm), spikelets/panicle, filled grains/panicle and test weight (g). This probably might be due to effective control of all kind of weeds during both early and late crop growth stages which ultimately created favourable microclimatic condition for proper growth and development of rice plant (Table 2). This confirms the finding of Walia *et al*. (2008).

All the weed control treatments brought significant increase in grain (25-52%) and straw yield (27-58%) as compared to season long crop weed competition. Among all treatments, significantly the highest rice grain yield (6.2 tonnes/ha) was obtained under weed free environment which was statistically similar to pre-emergence application of pretilachlor 750 g/ha followed by post-emergence application of cyhalofop-butyl 60 g/ha at 30 DAS (5.97 tonnes/ha) and pre-emergence application of butachlor 750 g/ha followed by post-emergence application of cyhalofop-butyl 60 g/ha 30 DAS (5.83 tonnes/ha) (Table 2). Amongst herbicidal treatments, lowest weed index (3.7%) were recorded with sequential application of pretilachlor (750 g/ha) and cyhalofop-butyl (60 g/ha) and found to be most effective in controlling complex weed flora (Table 2).

Keeping in the view, the soil health depending upon soil micro flora, soil activity of cyhalofop-butyl residues was also assessed, in terms of their influence on soil micro flora at the harvest of the crop.

Herbicidal treatments did not cause significant influence on the population of bacteria and actinomycetes. While the population of fungi was significantly lower in cyhalofop-butyl treated plot at 80 g/ha applied at 10 DAS as compared to untreated soil (weedy check and weedy free). Toxic effect of herbicide is normally reported more severe immediately after application particularly at the high level of concentration. The bacterial population is resilient in nature and reported to be recouped at 120 DAS after a short lag phase up to 60 DAS and evened out at harvest across the herbicidal treatments. Similar effect was reported on actinomycetes population (Table 3).

The residue of cyhalofop-butyl was also estimated in the soil at harvest for exploring the possibility of growing many crops in the same plot in sequence. It was found below the detectable level. which indicate the suitability and safety of the cyhalofop-butyl application for weed management in direct seeded rice (Fig 1).

Table 2 Effect of weed control treatments on yield and yield attributes of rice.

Treatment	Total weed density (No/m^2)	Total weed dry wt. (g/m^2)	Panicles/ m^2	Panicle length (cm)	Spikelets/ panicle	Filled grain/ panicle (No)	Test weight (g)	Grain yield (t/ha)	Straw yield (t/ha)	Weed index (%)
Cyhalofop-butyl @ 60 g/ha at 10 DAS	14.42 (207.35)	6.76 (45.30)	48.7	23.9	158.8	118.5	22.6	4.00	8.20	35.48
Cyhalofop-butyl @ 80 g/ha at 10 DAS	11.85 (140.)	5.94 (34.90)	58.7	24.6	169.2	121.0	22.9	5.41	12.42	12.74
Cyhalofop-butyl @ 60 g/ha at 20 DAS	11.80 (138.77)	6.03) (35.90)	62.2	25.5	165.7	138.8	22.6	4.94	10.20	20.32
Cyhalofop-butyl @ 80 g/ha at 20 DAS	10.19 (103.44)	5.13) (26.80)	86.0	27.0	172.3	137.7	24.9	5.50	12.70	11.29
Butachlor @ 1000 g/ha PE	12.56 (157.18)	6.13 (37.20)	71.8	24.2	168.3	130.0	22.4	4.44	9.00	28.39
Pretilachlor @ 1000 g/ha PE	11.72 (136.75)	5.83 (33.60)	78.9	24.2	170.6	132.8	23.0	4.62	9.20	25.48
Butachlor @ 750 g/ha PE fb cyhalofop-butyl @ 60 g/ha at 30 DAS	8.21 (66.94)	4.60 (20.80)	92.0	27.6	177.6	137.9	25.7	5.83	13.20	5.97
Pretilachlor @ 750 g/ha PE fb cyhalofop-butyl @60 g/ha at 30 DAS	7.74 (59.38)	4.53 (20.10)	98.0	28.1	179.6	140.3	25.9	5.97	13.60	3.71
Weedy check	16.98 (287.83)	10.72 (114.49)	15.0	20.0	136.1	108.9	20.1	3.00	6.00	51.61
Weed free	0.71 (0.00)	0.71 (0.00)	105.0	28.5	181	141.3	26.3	6.20	14.00	0.000
SEm ±	0.51	0.15	2.4	1.3	2.3	4.9	1.2	0.21	0.37	1.16
LSD (P=0.05)	1.54	0.44	7.1	3.8	6.8	14.8	NS	0.62	1.19	3.49

fb=Followed by, PE=Pre-emergence, DAS=Days after sowing. Data were subjected to $\sqrt{x+0.5}$ transformations before statistical analysis. Figure in parentheses are the original values.

Table 3 Effect of weed control treatment on microbial population in rice soil at harvest.

Treatments	Bacteria cfu 10^{-9}	Actino-mycetes cfu 10^{-4}	Fungi cfu 10^{-4}
Cyhalofop-butyl @ 60 g/ha at 10 DAS	275.20	24.20	6.40
Cyhalofop-butyl @ 80 g/ha at 10 DAS	276.40	25.80	5.79
Cyhalofop-butyl @ 60 g/ha at 20 DAS	278.10	26.10	6.20
Cyhalofop-butyl @ 80 g/ha at 20 DAS	276.90	24.68	6.00
Butachlor @ 1000 g/ha PE	270.00	26.20	5.90
Pretilachlor @ 1000 g/ha PE	280.00	25.20	6.00
Butachlor @ 750 g/ha PE fb cyhalofop-butyl @ 60g/ha at 30 DAS	272.00	24.68	6.10
Pretilachlor @ 750g/ha PE fb cyhalofop-butyl @ 60 g/ha at 30 DAS	276.00	25.24	6.00
Weedy check	279.50	26.30	7.20
Weed free	281.02	26.40	7.00
SEm ±	0.368	0.976	0.228
LSD (P=0.05)	NS	NS	0.68

DAS, Days after sowing, fb=Followed by; PE, Pre-emergence; cfu, Colony forming unit

SUMMARY

A field experiment was conducted during rainy season of 2009 at the research farm of the Indian Agricultural Research Institute, New Delhi to evaluate the appropriate combination of pre-emergence and post-emergence herbicides in direct-seeded rice (*Oryza sativa* L.). All the weed control treatments brought significant increase in grain (25-52%) and straw yield (27-58%) as compared to season long crop weed competition. Cyhalofop-butyl residues in soil were found below detectable level indicating safety to soil microbial population and succeeding crop. It may be concluded that weeds can be managed during critical period of competition with the sequential application of pretilachlor (750 g/ha) as pre-emergence followed by post-emergence application of cyhalofop-butyl (60 g/ha) at 30 DAS in direct-seeded rice.

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