Indian Journal of Weed Science **49**(3): 211–215, 2017
DOI: 10.5958/0974-8164.2017.00056.9

Assessment of post-emergence weed management in direct-seeded rice

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Received: 4 July 2017; Revised: 19 August 2017

ABSTRACT

The present study was carried out at G.B. Pant University of Agriculture and Technology, Pantnagar during rainy seasons 2014 and 2015 to determine the efficacy of post-emergence application of cyhalofop-butyl in managing weeds in direct-seeded rice. Eight treatments, *viz*. cyhalofop-butyl 10% EC at 65, 75, 80 and 90 g/ha, cyhalofop-butyl 10% EC at 75 and 80 g/ha, hand weeding twice at 20 and 40 DAS and untreated control were laid out in a randomized block design with three replications. Application of cyhalofop-butyl controlled grassy weeds better than the non-grassy weeds and recorded maximum weed control efficiency, higher yield attributes and yield. Application of cyhalofop-butyl in rice did not show any phytotoxic effect on succeeding wheat.

Key words: Cyhalofop-butyl, Herbicide, Herbicide efficiency index, Weed control efficiency, Yield

Rice (*Oryza sativa*) is a major cereal crop and staple food for more than half of the world's population. About 90% of the world's rice is produced and consumed in Asia (FAO 2014). The world's total rice area is 168 Mha and production is about 722 M tons with the productivity of 4.29 t/ha (FAOSTAT 2012). Puddling for transplanted rice cause to dispersion of soil particles and consequent compaction of the soil and is labour intensive (Chauhan *et al.* 2012). The direct-seeded rice (DSR) cultivation, which does not need puddling and transplanting was found as feasible alternative to save water and labour (Ghosh *et al.* 2016). DSR is a cost effective rice establishment method where dry seed is drilled into the non-puddled soil. This provides opportunities of saving irrigation water by 12-35%, labor up to 60% and provides higher net returns (US$ 30-50/ha) with similar or slightly lower yield of rice (Kumar and Ladha 2011). Despite multiple benefits of dry DSR, weed control remains one of the major challenges for its success in South Asia (Kumar and Ladha 2011, Rao *et al*. 2007, Singh *et al*. 2008). Since the concept of aerobic rice is new (Belder *et al.* 2005) growing rice under aerobic conditions on raised beds or flat land would require suitable, effective and economic weed-control methods. Both pre-emergence and post-emergence herbicides can be used in aerobic rice fields and they are effective, if properly used (De Datta and Baltazar 1996, Singh *et al*. 2006). In spite of use of different chemicals as pre-emergence and post-emergence, certain weeds like *Leptochloa chinensis* and other grassy weeds are still not controlled. Hence, the present study was undertaken to determine the efficacy of cyhalofop-butyl as post-emergence application against grassy weeds in direct-seeded rice.

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MATERIALS AND METHODS

The field experiment was conducted at GBPUA&T, Pantagar (29^{0}N latitude, 27.3^{0}E longitude and at an altitude of 243.8 m above the mean sea level) during the rainy season of 2014 and 2015. The climate of Pantnagar is very hot in summers and cold in winters. The hottest months are May and June, when the maximum temperature reaches 40^{0}C, whereas during December and January, the coldest month of the year, the minimum temperature often remains below 10^{0}C and may reach to 1^{0}C. The average rainfall is 1450 mm, 80% of which is received through the monsoon from June to September.

The experiment was laid out in a randomized block design with three replications. Eight treatment combinations were made up with different herbicides, hand weeding and weedy check as follows: Cyhalofop-butyl 10% EC at 65 g/ha, cyhalofop-butyl 10% EC at 75 g/ha, cyhalofop-butyl 10% EC at 80 g/ha, cyhalofop-butyl 10% EC at 90 g/ha, cyhalofop-butyl 10% EC (standard check) at 75 g/ha, cyhalofop-butyl 10% EC (std. check) at 80 g/ha, two hand weeding (20 and 40 days after sowing;

DAS) and weedy check. Herbicides were applied using a power operated knapsack sprayer fitted with a flat fan nozzle and water as a carrier at 500 liter/ha. In the weedy check, no weeding was done. For phytotoxicity study, cyhalofop-butyl 10% EC (std. check) was applied at 160 g/ha in direct-seeded rice. Rice ('*Sarjoo 52*') was seeded manually in line on 13th June, 2014 and 11th June, 2015 using seed rate of 50 kg/ha. Row to row spacing was 20 cm with continuous rice plants in a row. Thinning was done manually at 15 DAS to maintain plant population. Irrigation was applied in the field as per requirement. The soil was loamy, medium in organic matter (0.67%), available nitrogen (210 kg/ha), phosphorus (17.5 kg/ha) and potassium (181.2 kg/ha) with pH 7.5. Half of nitrogen, full dose of phosphorous and potash were applied as basal and remaining half of nitrogen was applied in two split doses first at active tillering and second at panicle initiation stage in all treatments. Observations were taken on density and biomass of weeds, weed control efficiency (WCE), herbicide efficiency index (HEI) and weed persistence index at 45 DAS by placing a quadrate of 0.25 m^2 at four randomly selected places. Removed weed flora was oven dried at 70^0C for 72 hours. Crop was harvested on October 27, 2014 and October 25, 2015 and left in the field for 5-7 days for sun drying. The number of panicles/m^2, grains/panicle, 1000 grain weight, grain yield, straw yield and grain straw ratio was recorded. Data were analyzed by using standard statistical techniques (STPR package). Phytotoxic symptoms were recorded in direct-seeded rice on 3, 7, 14, 21 and 28 days after herbicide application at a dose of 80 and 160 g/ha of cyhalofop-butyl by comparing it with weedy check. Carry over effect of applied herbicides also observed on succeeding wheat crop.

RESULTS AND DISCUSSION

Relative weed density

At 45 days after herbicide application (DAA) the experimental area of direct-seeded rice crop was infested with different grassy and non-grassy weeds during both the years of experimentation. Among grassy weeds *Echinochloa colona, E. crus-galli* and *Leptochloa chinensis* were dominant and among non-grassy weeds *Alternanthera sesillis, Caesulia axillaris, Cyperus iria* and *Cyperus rotundus* were major weeds. *Echinochloa colona, E. crus-galli, L. chinensis* and non-grassy weeds accounted 7.7, 7.7, 9.5 and 75.1% during 2014 and 4.1, 7.6, 4.7 and 83.6% relative weed density during 2015, respectively in weedy check plot (**Table 1**).

Density and dry biomass of weeds

During 2014, the minimum density and biomass of *E. colona* and *E. crus-galli* was recorded with the application of cyhalofop-butyl at 90 g/ha, which was comparable with its lower dose applied at 80 (both sponsor sample and std. check) and 75 g/ha while during 2015, all the herbicidal treatments except cyhalofop-butyl at 65 g/ha completely eliminated *E. colona* whereas the density as well as dry biomass of *E. crus-galli* was found minimum with the application of cyhalofop-butyl at 90 g/ha, which was at par with its lower dose applied at 75 and 80 g/ha. All the doses of cyhalofop-butyl except its lower dose at 65 g/ha recorded complete elimination of *L. chinensis* during both the years of experimentation while during 2015, std. check of cyhalofop-butyl at 75 g/ha also not achieved complete control over its density and dry biomass. None of the herbicidal treatments was found effective in controlling the density and dry biomass of non-grassy weeds over the weedy check treatment. Minimum density of grassy weeds is due to selectivity of herbicide. This herbicide was more effective against the grassy weeds as compared to broad leaf weeds and sedges and lowest dry biomass of grassy weeds might be due to low density of grasses as compared to non-grassy weeds.

Total weed dry biomass, WCE, HEI and WPI

Minimum total dry biomass of weeds was recorded with the post-emergence application of cyhalofop-butyl at 90 g/ha which was significantly superior to rest of the treatments except twice hand weeding at 20 and 40 DAS during 2014 while during 2015, cyhalofop-butyl applied at 90 g/ha as post-emergence was comparable with rest of the weed management practices except with the application of cyhalofop-butyl at 65 g/ha. Among different herbicidal treatments, application of cyhalofop-butyl at 90 g/ha as post-emergence recorded maximum weed control efficiency (WCE) of 70.2 and 74.0% during 2014 and 2015, respectively (**Table 3**).

Maximum herbicide efficiency index (HEI) was attained (21.7 and 13.9%) with the application of cyhalofop at 90 g/ha during 2014 and 2015, respectively, which was followed by its lower dose applied at 80 g/ha. During 2014, application of cyhalofop-butyl at 90 g/ha obtained minimum weed persistence index (WPI) (0.42%) that was followed by cyhalofop-butyl (std. check) at 80 g/ha, whereas, during 2015, cyhalofop-butyl (std. check) at 75 g/ha recorded lowest weed persistence index (0.32%), which was followed by cyhalofop-butyl at 90 g/ha

(**Figure 1**).Thus, with the increase in herbicide efficiency index, weed persistence index is decreases. As compared to 2015, in 2014 greater herbicide efficiency index as well as weed persistence index was recorded.

Table 1. Effect of treatment on weed density (no./m^2) at 45 days after herbicide application

Treatment	Grasses						Non grassy weeds	
	E. colona		*E. crus-galli*		*L. chinensis*			
	2014	2015	2014	2015	2014	2015	2014	2015
Cyhalofop-butyl (65 g/ha)	3.2(9.3)	1.7(2.0)	3.0(8.0)	2.4(4.7)	2.5(5.3)	4.7(2.4)	14.5(210.7)	13.4(179.3)
Cyhalofop-butyl (75 g/ha)	2.1(3.3)	1.0(0.0)	2.0(3.0)	1.5(1.3)	1.0(0.0)	1.0(0.0)	13.3(178.7)	13.2(174.7)
Cyhalofop-butyl (80 g/ha)	1.9(2.7)	1.0(0.0)	1.9(2.7)	1.2(0.7)	1.0(0.0)	1.0(0.0)	12.2(150.7)	13.0(168.7)
Cyhalofop-butyl (90 g/ha)	1.5(1.3)	1.0(0.0)	1.5(1.3)	1.0(0.0)	1.0(0.0)	1.0(0.0)	12.6(158.0)	13.4(178.7)
Cyhalofop-butyl (std. check) (75 g/ha)	2.5(5.3)	1.0(0.0)	2.5(5.3)	2.2(4.0)	1.0(0.0)	1.9(2.7)	12.0(142.7)	13.9(191.0)
Cyhalofop-butyl (std. check) (80 g/ha)	1.9(2.7)	1.0(0.0)	1.9(2.7)	1.9(2.7)	1.0(0.0)	1.0(0.0)	12.8(162.7)	13.2(174.7)
Hand weeding 20 and 40 DAS	2.5(5.3)	1.5(1.3)	2.2(4.0)	1.9(2.7)	3.2(9.3)	1.5(1.3)	7.9(62.7)	10.4(108.0)
Weedy check	4.3(17.3)	3.2(9.3)	4.3(17.3)	4.3(17.3)	4.7(21.3)	3.4(10.7)	13.0(168.7)	13.8(190.7)
LSD (p=0.05)	0.60	0.3	0.50	0.6	0.31	0.40	2.1	1.24

Value in parentheses was original and transformed to square root $(\sqrt{x+1})$ for analysis, DAS- Days after sowing

Table 2. Effect of treatment on weed dry biomass (g/m^2) at 45 days after herbicide application

Treatment	Grasses						Non grassy weeds	
	E. colona		*E. crus-galli*		*L. chinensis*			
	2014	2015	2014	2015	2014	2015	2014	2015
Cyhalofop-butyl (65 g/ha)	5.2(26.7)	2.6(5.8)	5.0(24.0)	3.1(8.5)	3.5(11.4)	2.1(3.4)	8.6(73.0)	8.1(65.2)
Cyhalofop-butyl (75 g/ha)	3.1(8.7)	1.0(0.0)	2.8(7.3)	1.7(2.0)	1.0(0.0)	1.0(0.0)	7.9(61.9)	8.0(63.5)
Cyhalofop-butyl (80 g/ha)	3.0(8.3)	1.0(0.0)	2.8(7.0)	1.3(0.8)	1.0(0.0)	1.0(0.0)	7.8(60.4)	7.8(60.1)
Cyhalofop-butyl (90 g/ha)	2.1(3.9)	1.0(0.0)	2.0(3.7)	1.0(0.0)	1.0(0.0)	1.0(0.0)	7.6(57.3)	7.7(59.0)
Cyhalofop-butyl (std. check) (75 g/ha)	4.1(16.2)	1.0(0.0)	4.0(14.9)	2.0(3.2)	1.0(0.0)	1.8(2.1)	7.5(55.5)	7.7(58.1)
Cyhalofop-butyl (std. check) (80 g/ha)	3.1(8.8)	1.0(0.0)	2.82(7.7)	1.9(2.7)	1.0(0.0)	1.0(0.0)	7.8(59.9)	7.6(57.7)
Hand weeding 20 and 40 DAS	4.2(16.6)	2.6(6.9)	3.6(12.3)	1.9(2.8)	4.2(16.4)	1.7(2.1)	4.8(22.3)	5.2(26.6)
Weedy check	7.8(60.3)	8.3(67.6)	7.1(49.2)	9.8(95.3)	6.7(44.5)	3.4(10.9)	8.0(63.5)	7.3(53.1)
LSD (p=0.05)	1.0	0.9	0.82	0.70	0.27	0.43	0.83	0.85

Value in parentheses was original and transformed to square root $(\sqrt{x+1})$ for analysis, DAS- Days after sowing

Table 3. Effect of treatments on total weed dry biomass and WCE at 45 DAA

Treatment	Total weed dry biomass(g/m^2)		Weed control efficiency (%)	
	2014	2015	2014	2015
Cyhalofop-butyl (65 g/ha)	11.7(135)	9.1(83)	37.9	63.5
Cyhalofop-butyl (75 g/ha)	9.4(87)	8.1(65)	60.0	71.1
Cyhalofop-butyl (80 g/ha)	8.8(77)	7.9(61)	64.7	73.2
Cyhalofop-butyl (90 g/ha)	8.1(65)	7.7(59)	70.2	74.0
Cyhalofop-butyl (std. check) (75 g/ha)	9.4(87)	8.0(63.4)	60.2	72.1
Cyhalofop-butyl (std. check) (80 g/ha)	8.8(76)	7.8(60)	64.8	73.4
Hand weeding 20 and 40 DAS	8.3(67)	6.3(38)	68.9	83.1
Weedy check	14.8(218)	15.1(227)	-	-
LSD (p=0.05)	0.40	0.77	-	-

Value in parentheses was original and transformed to square root $(\sqrt{x+1})$ for analysis, DAS- days after sowing, DAA- days after herbicide application and WCE- weed control efficiency.

Yield attributes

All yield attributing characters of rice crop, *viz.* number of panicles/m^2, grains/panicle and 1000 grain weight were significantly influenced by different weed control treatments during both the years of study except 1000-grain weight during 2014 (**Table 4**). Yield attributes data depicted highest value under twice hand weeding at 20 and 40 DAS during both the years. Within herbicidal treatments, application of cyhalofop-butyl at 90 g/ha achieved maximum panicles number of 232 and 253/m^2 during 2014 and 2015, respectively, which was at par with rest of the herbicidal treatments except cyhalofop-butyl applied at 65 g/ha. During 2014, cyhalofop-butyl applied at 90 g/ha and during 2015 application of cyhalofop-butyl at 80 g/ha obtained highest number of grains/ panicle, which was comparable to rest of the treatments. 1000-grain weight was maximum (24.5 g) with the application of cyhalofop-butyl at 80 g/ha which was significantly superior to cyhalofop-butyl applied at 65 g/ha. This might be due to less density and biomass of weeds, less crop weed competition during critical period, better environment for rice

growth at higher doses of cyhalofop-butyl, which in turn resulted in highest value for yield attributes of rice crop.

Grain and straw yield

The highest grain yield (4.21 and 4.29 t/ha) was found with the application of cyhalofop-butyl at 90 g/ha which was comparable with rest of the herbicidal treatments except with its lower dose applied at 65 g/ha (**Table 4**). The grassy weeds dominant at critical period of weed competition stage (**Table 1 and 2**) were well managed by cyhalofop-butyl. Menono *et al*. (2014) also reported that maximum rice yield with application of cyhalofop-butyl either applied as alone or in combination. The highest straw yield was recorded with the application of cyhalofop-butyl at 80

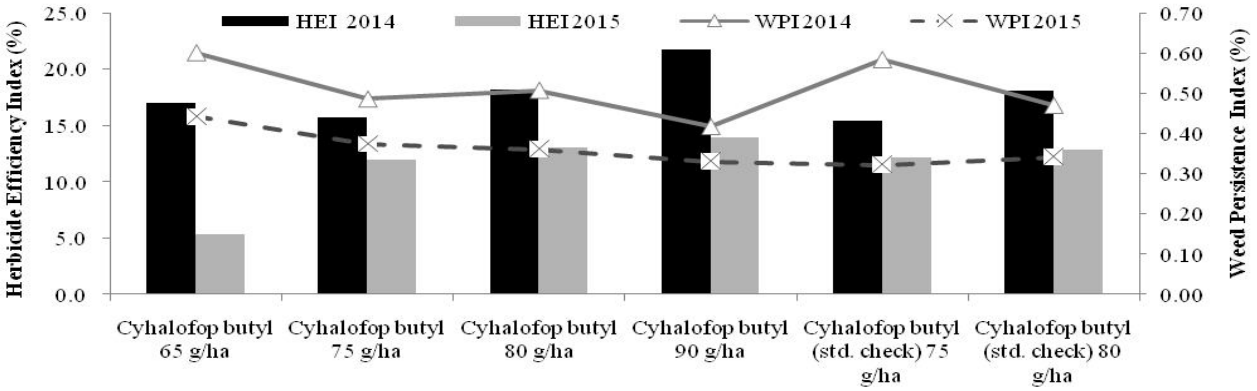

Figure 1. Effect of treatments on herbicide efficiency index (HEI) and weed persistence index duing (WPI) 2014 and 2015

Table 4. Rice yield and yield attributing characters of direct-seeded rice as affected by treatments

Treatment	Panicles (no./m^2)		Grains/ panicle		1000 grain weight (g)		Grain yield (t/ha)		Straw yield (t/ha)		Grain: Straw	
	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015	2014	2015
Cyhalofop-butyl(65 g/ha)	134	223	92.7	94.5	23.9	23.0	2.97	3.50	4.31	6.30	0.69	0.55
Cyhalofop-butyl (75 g/ha)	225	251	97.7	104.5	24.2	24.3	4.07	4.10	7.36	7.38	0.55	0.56
Cyhalofop-butyl (80 g/ha)	229	252	98.0	106.7	24.2	24.5	4.17	4.16	7.46	7.48	0.56	0.56
Cyhalofop-butyl (90 g/ha)	232	253	99.3	104.5	24.3	24.1	4.21	4.29	7.29	7.73	0.58	0.56
Cyhalofop-butyl (std. check)(75g/ha)	225	238	97.7	103.5	24.1	23.9	4.00	4.02	7.19	7.24	0.57	0.55
Cyhalofop-butyl (std. check)(80g/ha)	227	247	98.7	105.1	24.3	24.4	4.12	4.07	5.99	7.44	0.69	0.55
Hand weeding 20 and 40 DAS	246	265	109.3	111.3	24.1	24.7	4.25	4.34	6.67	7.81	0.64	0.56
Weedy check	112	138	54.0	67.0	23.6	22.2	0.65	1.19	1.17	2.13	0.56	0.56
LSD (p=0.05)	30.5	27.3	6.6	14.2	NS	1.36	0.38	0.29	0.48	0.50	-	-

DAS- days after sowing

Table 5. Effect of various doses of cyhalofop-butyl applied in rice on the succeeding wheat crop, *Rabi* season

Treatment	Plant population (m^2)		Spikes (no/m^2)		Grains/spike		1000 grain weight (g)		Grain yield (t/ha)		Straw yield (t/ha)	
	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16	2014-15	2015-16
Cyhalofop-butyl(65 g/ha)	262	229	296	329	42.6	41.3	44.4	39.4	4.39	4.02	6.41	6.90
Cyhalofop-butyl (75 g/ha)	256	224	285	307	43.1	40.5	44.4	40.2	4.30	4.20	6.47	7.14
Cyhalofop-butyl (80 g/ha)	256	225	273	309	43.0	41.5	44.2	39.0	4.46	4.20	6.36	7.15
Cyhalofop-butyl (90 g/ha)	234	230	292	275	41.6	40.5	43.5	40.3	4.14	4.01	6.52	6.81
Cyhalofop-butyl (std. check)(75g/ha)	245	223	304	304	42.7	41.0	45.1	39.1	4.52	4.14	6.46	6.98
Cyhalofop-butyl (std. check)(80g/ha)	241	225	288	298	42.4	40.4	45.7	39.5	4.10	4.10	7.05	6.97
Hand weeding 20 and 40 DAS	267	222	286	284	42.7	40.7	45.0	39.5	4.18	3.95	6.63	6.72
Weedy check	269	224	280	328	42.1	41.4	45.4	39.5	4.30	4.02	6.74	6.80
LSD (p=0.05)	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS	NS

DAS- days after sowing, NS- non significant

g/ha in 2014 and 90 g/ha during 2015, which were significantly superior to cyhalofop-butyl applied at 65 g/ha. The highest grain yield of rice was obtained with cyhalofop-butyl at 90 g/ha due to better control of grassy weeds. Maximum grain: straw ratio was recorded with cyhalofop-butyl at 65 g/ha and cyhalofop-butyl (std. check) at 80 g/ha (0.69) during 2014 and with application of cyhalofop-butyl at 75, 80 and 90 g/ha as well as twice hand weeding at 20 and 40 (0.56) during 2015.

Phytotoxicity

No phytotoxic symptoms were seen in direct-seeded rice crop due to application of cyhalofop-butyl at different doses on 3, 7, 14, 21 and 28 days after herbicide application during both the years.

Carryover effect

In succeeding wheat crop, the plant population at harvest as well as wheat yield and yield attributing characters were not influenced significantly due to various weed control treatments applied during preceding rice crop and they were statistically similar to each other. This concludes that post emergence application of cyhalofop-butyl against weeds in direct-seeded rice crop during rainy season was very safe for growing wheat crop during winter season (**Table 5**).

It was concluded that cyhalofop-butyl should be applied at 75 and 80 g/ha for better control of grassy weeds and maximum rice grain yield. The succeeding wheat crop had no phytotoxic effect due to application of cyhalofop-butyl.

ACKNOWLEDGEMENT

The authors gratefully acknowledge Crystal Crop Protection Pvt. Ltd. for financial assistance.

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