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Short communication

Tank mix application of cyhalofop-butyl with selected herbicides for weed control in wet-seeded rice

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Herbicidal weed control is becoming very common in rice cultivation in India (Rao *et al.* 2007). Recently farmers are opting for use of single application of herbicide mixtures in rice fields for broad-spectrum control of weeds. Cyhalofop-butyl is a cost -effective post- emergence selective herbicide that controls grass weeds especially *Echinochloa* spp. and *Leptochloa chinensis* (Saini *et al*. 2001). As it is not effective against sedges or broad-leaf weeds, a follow up application of broad spectrum herbicides is usually recommended. However, to reduce the cost of spraying, farmers prefer tank mix application of these herbicides to have broad spectrum weed control in a single application. However, this practice often leads to herbicide antagonism though synergistic effects are also reported. So the present study was conducted to find out the best herbicide that can be tank mixed with cyhalofop-butyl, so that effective control of weeds can be achieved, while reducing the cost of cultivation.

A field experiment was conducted during *Mundakan* season (September 2015 to January 2016) in a farmer's field at Alappad Kole lands (100 31' N latitude and 76013' E longitude and 1m below mean sea level) of Thrissur district. The soil was clayey in texture with pH 4.7, medium in organic carbon (1.25%), available phosphorous (18.14 kg/ha) and potassium (183.3 kg/ha) and low in available nitrogen (151.2 kg/ha). The average maximum and minimum temperature during the crop growing season was 32.35^{o}C and 23.63^{o}C respectively. The experiment was laid out in randomized block design (RBD) with 16 treatments and 3 replications (**Table 1**). Rice variety '*Uma (MO 16)*' was broadcasted on Sep 23, 2015 with a seed rate of 80 kg/ha. The recommended dose of fertilizers and plant protection measures were applied. The herbicidal treatments comprised of both tank mix and sequential application of cyhalofop-butyl with selected herbicides, *viz*. Almix®, ethoxysulforun, carfentrazone-ethyl, pyrazosulfuron-ehtyl, pretilachlor, pendimethalin. The treatments were cyhalofop-butyl (80 g/ha) + Almix® (4 g/ha), cyhalofop-butyl (80 g/ha) + ethoxysulfuron (15 g/ ha), cyhalofop-butyl (80 g/ha) + carfentrazone-ethyl (20 g/ha), cyhalofop-butyl (80 g/ha) + pyrazo-sulfuron-ehtyl (30 g/ha), cyhalofop-butyl (80 g/ha) + pretilachlor (500 g/ha) and cyhalofop-butyl (80 g/ ha) + pendimethalin (1000 g/ha), cyhalofop-butyl (80 g/ha) followed by (*fb*) Almix® (4 g/ha), cyhalofop-butyl (80 g/ha) *fb* ethoxysulfuron (15 g/ha), cyhalofop-butyl (80 g/ha) *fb* carfentrazone-ethyl (20 g/ha), pyrazosulfuron-ethyl (30 g/ha) *fb* cyhalofop-butyl (80 g/ha), pretilachlor (500 g/ha) *fb* cyhalofop-butyl (80 g/ha), pendimethalin (1000 g/ha) *fb* cyhalofop-butyl (80 g/ha), bispyribac-sodium (30 g/ ha), hand weeded control, unweeded control. Pre-emergence herbicides (pyrazosulfuron-ethyl, pretilachlor and pendimethalin) were sprayed at 6 days after sowing (DAS), while all tank mix applications were sprayed at 18 DAS and follow up post-emergent herbicides at 20 DAS (*ie.* 2 days after the application of cyhalofop-butyl). Herbicide spraying was done using knapsack sprayer with flood jet nozzle and the spray volume was 250 litters/ha. Hand weeding was carried out at 20 and 40 DAS. Weed count and weed dry weight was recorded at 30, 60 DAS and at harvest using 0.25 m^2 quadrat. Weed control efficiency (WCE) was worked out on the basis of dry weight of weeds. Data on weed count and dry weight were subjected to square root transformation before statistical analysis to make the analysis of variance valid (Gomez and Gomez, 1984).

Weed flora

Broad-leaf weeds were the major weeds present in the experimental area and they constituted about 52% of total weed flora, this was followed by grasses (40%) and sedges (8%) at 60 DAS. *Echinochloa stagnina*, *Ludwigia parviflora* and *Monochoria vaginalis* were the major weeds. Among broad-leaf

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weeds *Monochoria vaginalis* was the predominant one. Estorninos (1982) reported *Monochoria vaginalis* as a major weed in direct wet-seeded rice.

Weed density and biomass

Cyhalofop-butyl was very effective against grass weeds of rice at 30 DAS (**Table 2**). However, when cyhalofop-butyl was tank mixed with Almix®, the count of *Echinochloa stagnina* was next to that in unweeded control (**Table 1**). This clearly shows that cyhalofop-butyl losses its herbicidal when mixed with Almix®. Scott (2002) has reported reduction in cyhalofop-butyl activity when it was tank mixed with 2,4-D. At the same time, the plots treated with tank mix combination of cyhalofop-butyl with Almix® were free of sedges and broad leaf weeds at 30 DAS (**Table 2**). Hence, it can be inferred that when tank mixed with cyhalofop-butyl, Almix® do not loss its activity. Plots applied with cyhalofop-butyl alone or in sequential application with ethoxysulfuron and carfentrazone-ethyl gave complete control of *Echinochloa stagnina*.

Complete control of *Monochoria vaginalis* was obtained when Almix® was applied as both tank mix with cyhalofop-butyl and as follow up application. Follow up application of pendimethalin, bispyribac-sodium and hand weeded plot were also free of *Monochoria vaginalis* at 30 DAS. Tank mix combination of cyhalofop-butyl with ethoxysulfuron registered effective control of *M. vaginalis,* while the sequential application of these two herbicides was not so effective. Kuk *et al.* (2003) has reported occurrence of cross resistance in certain biotypes of *Monochoria vaginalis* to sulfonyl urea herbicides. Good control of *Ludwigia parviflora* was obtained in plots treated with tank mix combination of cyhalofop-butyl + Almix®, cyhalofop-butyl + carfen-trazone-ethyl, cyhalofop-butyl + pyrazosulfuron-ethyl, cyhalofop-butyl + pendimethalin. Sequential application of pyrazosulfuron-ethyl *fb* cyhalofop-butyl also gave complete control of *Ludwigia parviflora* similar to bispyribac-sodium.

At all stages of crop growth the highest weed dry matter production was registered in unweeded

Table 1. Weeds density (no./m^2) at 60 days after sowing (DAS) and at harvest

Treatment	*Monochoria vaginalis*		*Ludwigia parviflora*		*Echinochloa stagnina*		*Sacciolepis interrupta*		*Leptochloa chinensis*		*Cyperus difformis*	
	60 DAS	At harvest	60 DAS	At harvest	60 DAS	At harvest	60 DAS	At harvest	60 DAS	At harvest	60 DAS	At harvest
Cyhalofop-butyl	*4.40	4.93	4.18	4.40	0.71	0.71	0.71	0.71	0.71	0.71	1.46	1.94
	(19.33)	(24.37)	(17.11)	(19.37)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(1.67)	(3.33)
Cyhalofop-butyl + Almix®	2.24	2.97	2.48	2.00	5.13	5.02	1.87	0.71	0.71	0.71	0.71	2.39
	(5.00)	(8.80)	(5.67)	(4.00)	(25.80)	(24.67)	(3.00)	(0.00)	(0.00)	(0.00)	(0.00)	(5.33)
Cyhalofop-butyl + ethoxysulfuron	2.24	2.41	3.58	3.87	0.71	0.71	0.71	0.71	0.71	0.71	1.58	2.39
	(5.00)	(5.80)	(12.33)	(15.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(2.00)	(5.33)
Cyhalofop-butyl + carfentrazone-ethyl	3.11	3.27	2.55	2.83	0.71	0.71	0.71	0.71	0.71	0.71	1.23	1.65
	(9.67)	(10.73)	(6.00)	(8.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(1.00)	(2.67)
Cyhalofop-butyl + pyrazosulfuron-ethyl	2.16	2.48	1.63	1.41	2.92	2.92	0.71	0.71	0.71	0.71	0.71	0.71
	(4.67)	(6.17)	(2.26)	(2.00)	(8.00)	(8.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Cyhalofop-butyl + pretilachlor	4.20	4.36	3.85	3.74	1.92	0.71	0.71	0.71	0.71	0.71	2.39	0.71
	(17.67)	(19.00)	(14.33)	(14.00)	(3.20)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(4.67)	(0.00)
Cyhalofop-butyl + pendimethalin	2.71	2.65	2.37	2.75	3.45	3.85	1.77	0.71	0.71	0.71	0.71	1.92
	(7.33)	(7.00)	(5.13)	(7.57)	(11.40)	(14.33)	(2.67)	(0.00)	(0.00)	(0.00)	(0.00)	(4.00)
Cyhalofop-butyl *fb* Almix®	2.28	2.83	1.58	2.89	2.12	2.12	0.71	0.71	0.71	0.71	0.71	0.71
	(5.23)	(8.00)	(2.00)	(8.33)	(4.00)	(4.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Cyhalofop-butyl *fb* ethoxysulfuron	3.65	3.16	2.12	3.29	0.71	0.71	0.71	0.71	0.71	0.71	0.71	0.71
	(13.33)	(10.00)	(4.00)	(10.80)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
Cyhalofop-butyl *fb* carfentrazone-ethyl	3.00	3.16	1.89	3.82	0.71	0.71	0.71	0.71	0.71	0.71	2.39	2.27
	(9.00)	(10.00)	(3.13)	(14.57)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(5.33)	(4.67)
Pyrazosulfuron-ethyl *fb* Cyhalofop-butyl	2.94	3.16	0.71	1.68	0.71	0.71	0.71	0.71	0.71	0.71	2.39	2.27
	(8.67)	(10.00)	(0.00)	(2.80)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(5.33)	(4.67)
Pretilachlor *fb* cyhalofop-butyl	2.83	2.92	2.14	2.45	0.71	0.71	0.71	0.71	0.71	0.71	2.12	2.12
	(8.00)	(8.57)	(4.13)	(6.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)	(4.00)	(4.00)
Pendimethalin *fb* cyhalofop-butyl	1.84	2.00	2.74	2.91	2.12	2.86	1.34	0.71	0.71	0.71	2.39	1.65
	(3.40)	(4.00)	(7.00)	(8.48)	(4.00)	(7.67)	(1.33)	(0.00)	(0.00)	(0.00)	(5.33)	(2.67)
Bispyribac sodium	2.52	2.49	1.87	2.24	0.71	0.71	0.71	0.71	1.94	2.41	0.71	0.71
	(6.33)	(6.20)	(3.00)	(5.00)	(0.00)	(0.00)	(0.00)	(0.00)	(3.26)	(5.33)	(0.00)	(0.00)
Hand weeding	1.52	1.73[j]	1.87	1.84	0.71	1.58	0.71[d]	0.71	0.71	1.05	0.71	0.71
	(2.33)	(3.00)	(3.00)	(3.40)	(0.00)	(2.00)	(0.00)	(0.00)	(0.00)	(0.67)	(0.00)	(0.00)
Unweeded control	5.75	6.21	3.94	4.36	4.64[b]	4.34[b]	2.70[a]	0.71	3.08	3.24	2.65	3.00
	(33.00)	(38.60)	(15.00)	(19.00)	(21.00)	(18.33)	(6.80)	(0.00)	(9.00)	(10.0)	(6.67)	(8.67)
LSD(P = 0.05)	0.16	0.19	0.32	0.15	0.08	0.07	0.12	0.00	0.05	0.14	0.40	0.77

Almix® - (metsulfuron methyl 10% + chlorimuron ethyl 10% WP) control and it almost doubled by 60 DAS, but only a marginal increase was noted from 60 DAS to harvest. Among tank mix application of herbicides, cyhalofop-butyl + pyrazosulfuron-ethyl recorded the least weed dry matter production while among various sequential application of herbicides, the lowest weed dry matter accumulation was noted in cyhalofop-butyl *fb* Almix® at all stages of observation.

Weed control efficiency

Cent per cent WCE was observed in hand weeded treatment at 30 DAS and even at harvest stage 93% WCE was observed. Rice grain yield was 45% higher than unweeded control. Among the herbicide treatments, tank mix combination of cyhalofop-butyl + pyrazosulfuron-ethyl recorded higher rice grain and straw yield which was at par with post-emergence application of bispyribac-sodium. The higher values under these treatments resulted from lesser crop-weed competition. It can also be inferred that either tank mix application of cyhalofop-butyl + pyrazosulfuron-ethyl or bispyribac-sodium is adequate to manage the weeds.

Yield and economics

The lowest rice yield was recorded in unweeded control, which was due to high weed density and biomass that adversely affected all the yield parameters. Kumar *et al.* (2013) observed a yield reduction to the tune of 48% in wet-seeded rice due to severe weed competition.

Highest B:C ratio as well as net return was obtained in cyhalofop-butyl + pyrazosulfuron-ethyl (**Table 3**). This is due to high rice grain and straw yield as well as saving in cost of spraying due to tank mix application. The next best treatment with respect to net returns was bispyribac-sodium. The difference in net returns over the best treatment was ` 5000/ha. Bispyribac-sodium application per hectare costed ` 4596. For tank mix combination of cyhalofop-butyl + pyrazosulfuron-ethyl, the cost involved was only ` 2841/ha (` 1776 for 800 ml of cyhalofop-butyl and `

Table 2. Effect of weed management treatments on weed density and biomass

Treatment	Weed density (no./m^2)									Weed biomass (kg/ha)		
	30 DAS			60 DAS			harvest					
	G	S	B	G	S	B	G	S	B	30 DAS	60 DAS	Harvest
Cyhalofop-butyl	*0.7	1.6	5.1	0.7	1.5	6.0	0.7	1.9	6.4	*17.6	19.9	20.1
	(0.0)	(2.0)	(26.0)	(0.0)	(1.7)	(36.4)	(0.0)	(3.3)	(43.7)	(309.5)	(398.7)	(403.9)
Cyhalofop-butyl + Almix®	4.9	0.7	0.7	5.4	0.7	3.3	5.0	2.4	3.6	11.6	16.2	15.2
	(24.0)	(0.0)	(0.0)	(28.8)	(0.0)	(10.7)	(24.7)	(5.3)	(12.8)	(134.4)	(261.3)	(234.7)
Cyhalofop-butyl + ethoxysulfuron	0.7	1.3	3.7	0.7	1.6	4.2	0.7	2.4	4.6	12.4	13.9	16.8
	(0.0)	(1.3)	(13.3)	(0.0)	(2.0)	(17.3)	(0.0)	(5.3)	(20.8)	(153.9)	(197.3)	(282.8)
Cyhalofop-butyl + carfentrazone-ethyl	0.7	1.5	3.5	0.7	1.2	3.9	0.7	1.7	4.3	12.5	11.3	14.7
	(0.0)	(1.7)	(12.0)	(0.0)	(1.0)	(15.6)	(0.0)	(2.7)	(18.7)	(157.3)	(130.5)	(218.1)
Cyhalofop-butyl + pyrazosulfuron-ethyl	2.7	0.7	2.4	2.9	0.7	2.6	2.9	0.7	2.8	8.7	9.7	11.2
	(6.7)	(0.0)	(5.3)	(8.0)	(0.0)	(6.9)	(8.0)	(0.0)	(8.2)	(77.3)	(96.8)	(128.0)
Cyhalofop-butyl + pretilachlor	1.8	1.5	5.0	1.7	2.4	5.7	0.7	0.7	5.7	17.5	17.7	16.7
	(2.7)	(1.7)	(24.7)	(3.2)	(4.7)	(32.1)	(0.0)	(0.0)	(33.0)	(307.7)	(312.3)	(280.5)
Cyhalofop-butyl + pendimethalin	3.5	0.7	3.1	3.9	0.7	3.5	3.8	1.9	3.8	14.9	13.6	15.3
	(12.0)	(0.0)	(9.3)	(14.4)	(0.0)	(12.1)	(14.3)	(4.0)	(14.6)	(221.4)	(185.1)	(234.1)
Cyhalofop-butyl *fb* Almix®	0.7	0.7	2.4	2.1	0.7	2.7	2.1	0.7	4.1	7.3	11.0	13.8
	(0.0)	(0.0)	(5.3)	(4.0)	(0.0)	(7.3)	(4.0)	(0.0)	(16.3)	(52.9)	(121.4)	(190.4)
Cyhalofop-buyl *fb* ethoxysulfuron	0.7	1.2	4.4	0.7	0.7	4.2	0.7	0.7	4.6	11.9	11.4	14.5
	(0.0)	(1.0)	(18.7)	(0.0)	(0.0)	(17.3)	(0.0)	(0.0)	(20.8)	(100.4)	(130.0)	(212.2)
Cyhalofop-butyl *fb* carfentrazone-ethyl	0.7	1.5	3.1	0.7	2.4	3.5	0.7	2.3	3.8	12.2	11.9	12.1
	(0.0)	(1.7)	(9.3)	(0.0)	(5.3)	(12.1)	(0.0)	(4.7)	(14.6)	(150.8)	(144.9)	(148.5)
Pyrazosulfuron-ethyl *fb* cyhalofop-butyl	0.7	0.7	2.7	0.7	2.4	2.9	0.7	2.3	3.6	10.7	10.9	11.4
	(0.0)	(0.0)	(6.7)	(0.0)	(5.3)	(8.7)	(0.0)	(4.7)	(12.8)	(117.3)	(118.9)	(130.8)
Pretilachlor *fb* cyhalofop-butyl	0.7	1.2	3.1	0.7	2.1	3.5	0.7	2.1	3.8	11.7	11.4	12.1
	(0.0)	(1.0)	(9.3)	(0.0)	(4.0)	(12.1)	(0.0)	(4.0)	(14.6)	(137.3)	(131.4)	(148.5)
Pendimethalin *fb* cyhalofop-butyl	1.8	1.5	2.9	2.4	2.4	3.2	2.8	1.7	3.5	11.7	12.6	12.3
	(2.7)	(1.7)	(6.67)	(5.3)	(5.3)	(10.4)	(7.7)	(2.7)	(12.5)	(142.3)	(161.7)	(154.5)
Bispyribac-sodium	0.7	0.7	0.7	1.7	0.7	3.0	2.4	0.7	3.3	0.7	9.1	10.6
	(0.0)	(0.0)	(0.0)	(2.7)	(0.0)	(9.3)	(5.3)	(0.0)	(11.2)	(0.0)	(84.9)	(114.2)
Hand weeding	0.7	0.7	0.7	0.7	0.7	2.3	1.8	0.7	2.5	0.7	6.2	8.8
	(0.0)	(0.0)	(0.0)	(0.0)	(0.0)	(5.3)	(2.7)	(0.0)	(6.4)	(0.0)	(40.0)	(80.2)
Unweeded control	5.6	2.41	5.7	6.1	2.7	6.9	5.4	3.0	7.6	23.8	31.8	33.6
	(30.7)	(5.3)	(32.0)	(36.8)	(6.7)	(48.0)	(28.3)	(8.7)	(57.6)	(566.6)	(1010.5)	(1133.2)
LSD(p=0.05)	0.4	0.2	0.6	0.5	0.4	0.7	0.3	0.8	0.7	2.1	2.2	2.1

* $\sqrt{x+0.5}$ transformed values, Original values in parentheses. G- Grasses, S- Sedges, B- Broad-leaf weeds; DAS = Days after seeding

Table 3. Economics of rice cultivation of rice as affected by weed management with various herbicides and their combinations

Treatment	Weed control efficiency (%)		Grain yield (t/ha)	Straw yield (t/ha)	Total cost (x10^3 `)	Gross income (x10^3 `)	Net income (x10^3 `)	B:C ratio	Additional cost for weed management (x10^3 `)	Additional returns due to weed management (x10^3 `)
	30 DAS	60 DAS								
Cyhalofop-butyl	45.2	60.6	3.8	4.2	50.87	1,16.21	65.34	2.3	3.78	36.78
Cyhalofop-butyl + Almix®	76.3	73.8	3.8	3.8	51.39	1,15.09	63.70	2.2	4.29	35.15
Cyhalofop-butyl + ethoxysulfuron	72.8	85.0	3.7	3.6	51.41	1,10.34	58.93	2.1	4.31	30.38
Cyhalofop-butyl + carfentrazone-ethyl	72.4	87.6	3.9	3.9	51.41	1,17.26	65.85	2.3	4.31	37.30
Cyhalofop-butyl + pyrazosulfuron-ethyl	86.4	90.7	4.3	4.4	51.91	1,30.15	78.24	2.5	4.84	49.69
Cyhalofop-butyl + pretilachlor	45.7	69.6	3.8	3.9	53.22	1,13.78	60.55	2.1	6.13	32.00
Cyhalofop-butyl + pendimethalin	60.9	83.0	3.9	3.9	52.54	1,15.94	63.40	2.2	5.44	34.85
Cyhalofop-butyl *fb* Almix®	90.7	92.4	4.1	4.1	53.39	1,23.70	70.31	2.3	6.29	41.76
Cyhalofop-butyl *fb* ethoxysulfuron	75.1	87.0	4.1	4.1	53.41	1,23.35	69.94	2.3	6.31	41.39
Cyhalofop-butyl *fb* carfentrazone-ethyl	73.3	85.6	4.0	3.9	53.41	1,19.40	65.99	2.2	6.31	37.44
Pyrazosulfuron-ethyl *fb* cyhalofop-butyl	79.1	88.1	4.2	4.1	53.94	1,23.98	70.04	2.3	6.84	41.49
Pretilachlor *fb* cyhalofop-butyl	75.9	87.0	4.1	4.1	55.22	1,23.37	68.14	2.2	8.13	39.59
Pendimethalin *fb* cyhalofop-butyl	75.19[d]	84.0	4.1	4.1	54.54	1,23.32	68.78	2.3	7.44	40.23
Bispyribac sodium	100.0	91.6	4.2	4.2	53.69	1,26.93	73.24	2.4	6.60	44.68
Hand weeding	100.0	96.1	4.5	4.6	74.10	1,35.73	61.63	1.8	27.00	33.08
Unweeded control	-	-	2.5	2.7	47.10	75.65	28.55	1.6	-	-
LSD (p=0.05)	8.9	4.6	0.2	0.3						

1065 for 300 g of pyrazosulfuron-ethyl). Thus there was a saving of ` 1755/ha in cost of herbicide alone, due to this combination.

SUMMARY

The experiment was conducted during September 2015 to January 2016 in a farmer's field one meter below of mean sea level in Thrissur district of Kerala. Tank mix application of cyhalofop-butyl (80 g/ha) with pyrazosulfuron-ethyl (30 g/ha) at 18 DAS gave effective control of mixed weed flora in wet-seeded rice. It is not advisable to tank mix cyhalofop-butyl with Almix® as it will lead to complete loss of activity of cyhalofop-butyl. Tank mixing of pre emergence herbicides with cyhalofop-butyl was found to be less effective than their sequential application.

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