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Weed management with ready-mix herbicides in wet seeded rice

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ABSTRACT

The efficacy of new ready-mix herbicides i.e., pendimethalin + penoxsulam, cyhalofop-butyl + penoxsulam and florpyrauxifen-benzyl + cyhalofop-butyl were evaluated in direct-wet seeded rice. They were compared with the sequential application of cyhalofop-butyl fb (chlorimuron ethyl 10% + metsulfuron methyl 10%), bispyribac sodium, as well as hand weeded and unweeded controls. At 30 DAS, the lowest dry matter production was obtained in florpyrauxifen-benzyl + cyhalofop-butyl applied at 12 DAS. Nutrient removal followed a similar trend to weed dry weight. Highest grain yield was obtained in hand weeded control, which was found at par with all ready-mix herbicide treatments. Higher net returns and B:C ratios were obtained with ready-mix herbicides than with hand weeding.

Keywords : Cyhalofop-butyl + penoxsulam, florpyrauxifen-benzyl + cyhalofop-butyl and pendimethalin + penoxsulam

India is the second largest producer as well as consumer of rice in the world. The productivity of rice is dependent on the stress levels induced by several abiotic and biotic factors. Weeds are considered as the most serious pests among the biotic stresses caused to rice plants. In direct wet seeded rice, weed losses due to weed competition could go up to 100% if weeds were not controlled throughout the season (Singh *et al.*, 2014).

Several new ready-mix herbicides, which control all types of weeds, are now available in the market.These could overcome the requirement of more labour for tank mixing the herbicides. The possibility of lack of compatibility between herbicides could also be avoided. It is essential to find out the optimum time of application of these new herbicides so as to bring the weed population below the threshold level. This study was undertaken to evaluate the effectiveness of these new products on wet seeded rice in Kerala.

MATERIALS AND METHODS

The experiment was conducted during *Mundakan*season, from October 2019 to January 2020 in *Kole* areas of Alappad, Thrissur district. The rice variety 'Manuratna' (short duration, high yielding) was broadcasted under puddled conditions. The soil belonged to the order Inceptisols with pH 4.7and was low in nitrogen and medium in phosphorus and potassium. The plot size adopted was 20 m^2.

The experiment was laid out in randomized block design with 10 treatments replicated thrice. Three new ready-mix herbicides were applied at two different times of crop growth stages i.e., pendimethalin + penoxsulam at 625g ha^{-1} on 5 and 10 DAS, cyhalofop-butyl + penoxsulam at 135g ha^{-1}on 12 and 18 DAS, and florpyrauxifen-benzyl + cyhalofop-butyl at 150gha^{-1}on 12 and 18 DAS which were evaluated along with the sequential application of cyhalofop-butyl *fb* (chlorimuron ethyl 10% + metsulfuron methyl 10%) at 80+4gha^{-1}on 18 and 19 DAS, bispyribac sodium at 25gha^{-1}on 18 DAS, hand weeded (at 20 and 40 DAS), and unweeded control.

At 30 and 60 days after sowing the weed density was determined by the quadrat method. Dry weight of the weeds was determined after oven drying. Nutrient content of weedwas estimated using standard procedures. In rice, both at 30 and 60 days after sowing, the height of plants (cm) and tiller count per m^2 were recorded. At harvest, grain yields (tha^{-1}) were determined.

Economics of rice production was worked out based on the market value of produce. Statistical processing of data was done with OPSTAT to evaluate the difference between treatments.

RESULTS AND DISCUSSION

Weed population

At both 30 and 60 DAS, grasses were the dominant weeds followed by sedges, and the highest weed density of all the weed species was noticed in unweeded control.Weedy rice was a major weed in all the plots.At 30 DAS, all the plots were infested with weedy rice due to the large soil seed bank from the previous seasons. More than 80 per cent of the grass weeds was constituted by weedy rice. An average density of weedy rice of 7.4 nos.m^{-2} was observed in all the plots.

At 60 DAS, the lowest density of weedy rice(11 nos.m^{-2})was seen in hand weeded control, probably due to the second hand weeding performed at 40 DAS. The

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population of weedy rice gradually increased in all the treatments over time. Although the herbicides were ineffective in controlling weedy rice, a considerable reduction in weedy rice population was observed in the herbicide treated plots compared to the unweeded control, probably because of better growth of rice due to less competition from weeds.

At 30 DAS, *Echinochloa stagnina* was not observed in plots treated with cyhalofop-butyl + penoxsulam, cyhalofop-butyl + florpyrauxifen-benzyl, and in bispyribac sodium. It was also absent in hand weeded control. At 60 DAS the complete control of *Echinochloa stagnina* was observed in the plots treated with cyhalofop-butyl + penoxsulam and florpyrauxifen-benzyl + cyhalofop-butyl, both applied at 12 DAS, bispyribac sodium and hand weeded control. Also, considerable reduction in count was seen in all the other plots, with highest count in unweeded control.

Leptochloa chinensis, a grass weed, not observed at 30 DAS, was highest in the plot treated with bispyribac sodium at 60 DAS, which led to the high weed dry weight. In the remaining plots,the density was very low.

At 30 DAS, *Cyperus* spp was not observed in plots treated with pendimethalin + penoxsulam applied at 5 and 10 DAS and florpyrauxifen-benzyl + cyhalofop-butyl applied at 12 and 18 DAS. All the remaining plots had an average density of 6 nos.m^{-2}. At 60 DAS, complete control of *Cyperus*spp was observed in plots treated with pendimethalin + penoxsulamapplied at 5 DAS and florpyrauxifen-benzyl + cyhalofop-butyl at 12 DAS. At 30 DAS, the sedge *Fimbristylis miliacea* was noticed. However, at 60 DAS, it was completely controlled in all the herbicide treated plots.

The broadleaved weeds, *Ludwigia perennis* and *Limnophila heterophylla* were completely controlled in all the herbicide treated plots at both 30 and 60 DAS. The population of broadleaved weeds was comparatively low in the study area and at later stages, it was completely absent. *Eichhornia crassipes*, a minor weed in the experimental area, was only seen in the unweeded control at 60 DAS.

At 30 DAS, the lowest total weed density was observed in florpyrauxifen-benzyl + cyhalofop-butyl applied at 12 DAS,which was on par with florpyrauxifen-benzyl + cyhalofop-butyl applied at 18DAS The treatment pendimethalin + penoxsulam applied at 5 DAS came next and was at par with hand weeded control (Table 1).

At 60 DAS, the lowest weed count was noticed in hand weeded control followed by florpyrauxifen-benzyl + cyhalofop-butyl applied at 12 DAS which was on par with pendimethalin + penoxsulam applied at 5 DAS.

Considering the time of application of the three ready-mix herbicides, pendimethalin + penoxsulam applied at 5 DAS, and cyhalofop-butyl + penoxsulam and florpyrauxifen-benzyl + cyhalofop-butyl, both applied at 12 DAS, recorded lower weed density as compared to application at other stages.

Weed dry matter production

At 30 DAS lowest weed dry matter production (WDMP) was recorded on application of florpyrauxifen-benzyl + cyhalofop-butyl at 12 DAS, followed by the same combination applied at 18 DAS, which was at par with pendimethalin + penoxsulam applied at both 5 DAS and 10 DAS. All the treatments recorded WDMP lower than the hand weeded control (Table 1).

At 60 DAS the lowest WDMP was recorded in hand weeded control followed by the pre-mix herbicide treatments florpyrauxifen-benzyl + cyhalofop-butyl applied at 12 DAS and pendimethalin + penoxsulam applied at 5 DAS.

At both 30 DAS and 60 DAS, the performance of all the pre-mix herbicides was found superior to cyhalofop-butyl *fb* (chlorimuron ethyl 10% + metsulfuron methyl 10%), bispyribac sodium and unweeded control.

With regard to time of application, at 30 DAS the pre-mix herbicides pendimethalin + penoxsulam and cyhalofop-butyl + penoxsulam both sprayed at later stage,and florpyrauxifen-benzyl + cyhalofop-butyl applied at earlier stage recorded lower WDMP. However, by 60 DAS all the pre-mix herbicides applied at earlier stage resulted in lower WDMP.

Nutrient removal by weeds

At all stages of observation, lowest nutrient removal by weeds was recorded in hand weeded control and the highest removal was in unweeded control. At 30 DAS,weeds in unweeded control removed 10.78, 0.93 and 5.5 kg N, P and Krespectively per ha, and at 60 DAS it removed 25.98, 4.27 and 15.75 kg N, P and K respectively per ha. At both stages, the demand for nutrient uptake was in the order of nitrogen > potassium > phosphorus (Table 2).

Among the herbicide treatments, the lowest N removal at 60 DAS was recorded in florpyrauxifen-benzyl + cyhalofop-butyl applied at 12 DAS (3.52 kgha^{-1}), which was found at par with pendimethalin + penoxsulam applied at 5 DAS, and cyhalofop-butyl + penoxsulam and florpyrauxifen-benzyl + cyhalofop-butyl, both applied at 18 DAS. The lowest P removal was observed in florpyrauxifen-benzyl + cyhalofop-butyl applied at 12 DAS (0.92 kg ha^{-1}) and K removal was also lowest in the same pre-mix herbicide treatment (2.84 kg ha^{-1}).

Growth parameters of rice

In rice, at 30 DAS, 60 DAS and at harvest, there was no significant difference between the treatments with regard to plant height and the average plant heights were 51.19 cm, 87.95 cm and 96.97 cm respectively (Table 3). At 30 DAS there was no significant difference between the treatments with respect to the tiller number of rice per m^2. However, at 60 DAS the highest tiller count (325 nos.m^{-2}) was observed in hand weeded control which was at par with pendimethalin + penoxsulam sprayed at 10 DAS (323 nos.m^{-2}), probably due to the weed free environment resulted by the effectual weed control with the broad spectrum herbicide. Uraon (2019) reported that the pre-mix herbicide combination pendimethalin +penoxsulam applied at 7 DAS registered greatest number of tillers over the hand weeded check. Both at 30 and 60 DAS the lowest tiller count was observed in unweeded control.

Assessing the effect of time of application of the herbicide combinations, the highest tiller count was recorded in pendimethalin + penoxsulam applied at 10 DAS, cyhalofop-butyl + penoxsulam applied at 18 DAS and florpyrauxifen-benzyl + cyhalofop-butyl applied at 12 DAS over the same herbicidal sprays applied at other stages of growth of weeds.

Grain yield of rice

The highest grain yield of 4.6 tha^{-1} was recorded in hand weeded control, followed by florpyrauxifen-benzyl + cyhalofop-butyl applied at 12 DAS with 4.5tha^{-1} which were at par to each other and to pendimethalin + penoxsulam applied at 5 DAS (Table 3).

All the pre-mix herbicides were found superior to the sequential application of cyhalofop-butyl *fb* (chlorimuron ethyl 10% + metsulfuron methyl 10%), bispyribac sodium and unweeded control. This might be due to the excellent weed control acquired at 30 DAS, which fell within the crop-weed competition period i.e., from 15-45 DAS in rice.

With regard to time of application, the highest grain yields were recorded in pendimethalin + penoxsulam applied at 5 DAS, and cyhalofop-butyl + penoxsulam and florpyrauxifen-benzyl + cyhalofop-butyl, both applied at 12 DAS.

Weed index

Extent of yield reduction was recorded as highest in unweeded control to the tune of 56.74% and the lowest in florpyrauxifen-benzyl + cyhalofop-butyl applied at 12 DAS upto2.17% (Table 3).

Economic analysis

The highest net returns were obtained in two treatments, florpyrauxifen-benzyl + cyhalofop-butyl applied at 12 DAS and pendimethalin + penoxsulam applied at 5 DAS with Rs.90286 $ha^{-1}$and Rs.88080 ha^{-1}, respectively. The B:C ratio was 2.5 for both these treatments (Table 4). Madhavi *et al.* (2018) found that pre-emergence application of herbicide combination pendimethalin + penoxsulam at 4-7 DAS/DAT gave the highest benefit:cost ratio as compared to other treatments.

All the pre-mix herbicides recorded higher B:Cratio ranging from 2.3 to 2.5. The sequential application of cyhalofop-butyl *fb* (chlorimuron ethyl 10% + metsulfuron methyl 10%) and bispyribac sodium both recorded B:C ratio of 1.9. The highest total income was noted in hand weeded plots with Rs.1,52,220ha^{-1}, but due to higher cultivation cost, net returns as well as B:C ratio were lower.

All the pre-mix herbicides evaluated were found superior to the other herbicides in terms of grain yields.

Table 1. Effect of pre-mix herbicides on total weed density and weed dry weight

Treatments	Total weed density (No.m^{-2})		Weed dry weight (gm^{-2})	
	30 DAS	60 DAS	30 DAS	60 DAS
Pendimethalin + penoxsulam, 5 DAS	6.66	23.97	3.70	24.66
Pendimethalin + penoxsulam, 10 DAS	10.00	28.34	3.66	26.50
Cyhalofop-butyl + penoxsulam, 12 DAS	12.00	31.99	5.43	33.66
Cyhalofop-butyl + penoxsulam, 18 DAS	19.67	39.32	4.93	34.66
Florpyrauxifen-benzyl + cyhalofop-butyl, 12 DAS	4.00	21.66	3.53	22.33
Florpyrauxifen-benzyl + cyhalofop-butyl, 18 DAS	4.33	24.65	3.56	26.33
Cyhalofop-butyl *fb**Almix 18 DAS and 19 DAS	28.67	41.64	7.26	35.00
Bispyribac sodium, 18 DAS	15.33	35.98	7.63	38.66
Hand weeding, 20 DAS and 40 DAS	7.00	11.33	4.23	9.66
Unweeded control	47.34	76.65	2.31	131.02
LSD (0.05)	**0.13**	**0.28**	**5.59**	**3.32**
SEm(±)	**0.04**	**0.09**	**1.87**	**1.11**

*Almix – commercial formulation of chlorimuron-ethyl 10% + metsulfuron-methyl 10%

Table 2. Effect of pre-mix herbicides on nutrient removal by weeds

Treatments	N removal (kg ha^{-1})		P removal (kg ha^{-1})		K removal (kg ha^{-1})	
	30 DAS	60 DAS	30 DAS	60 DAS	30 DAS	60 DAS
Pendimethalin + penoxsulam, 5 DAS	1.10	4.03	0.18	1.02	0.68	3.23
Pendimethalin + penoxsulam, 10 DAS	1.35	5.25	0.20	1.23	0.64	3.32
Cyhalofop-butyl + penoxsulam, 12 DAS	2.19	5.11	0.23	1.27	0.98	4.26
Cyhalofop-butyl + penoxsulam, 18 DAS	1.47	4.04	0.28	1.28	0.93	4.44
Florpyrauxifen-benzyl + cyhalofop-butyl, 12 DAS	1.46	3.52	0.17	0.92	0.71	2.84
Florpyrauxifen-benzyl + cyhalofop-butyl, 18 DAS	1.58	3.87	0.20	0.94	1.04	3.04
Cyhalofop-butyl *fb* Almix, 18 DAS and 19 DAS	2.88	6.13	0.36	1.41	2.03	4.30
Bispyribac sodium, 18 DAS	3.03	6.31	0.29	1.34	1.74	6.65
Hand weeding, 20 DAS and 40 DAS	0.70	1.69	0.16	0.37	0.46	1.19
Unweeded control	10.78	25.98	0.93	4.27	5.50	15.75
LSD (0.05)	**0.49**	**0.56**	**0.03**	**0.04**	**0.15**	**0.15**
SEm(±)	**0.16**	**0.19**	**0.01**	**0.02**	**0.05**	**0.05**

Table 3. Effect of pre-mix herbicide combinations on rice plant height, tiller count, grain yield and weed index

Treatments	Plant height (cm)			No. of tillers per m^2		Grain yield (tha^{-1})	Weed index (%)
	30 DAS	60 DAS	Harvest	30 DAS	60 DAS		
Pendimethalin + penoxsulam, 5 DAS	49.30	85.40	94.77	125	262	4.43	3.70
Pendimethalin + penoxsulam, 10 DAS	50.60	86.26	97.78	136	323	4.29	6.74
Cyhalofop-butyl + penoxsulam, 12 DAS	53.43	88.03	95.52	130	247	4.38	4.78
Cyhalofop-butyl + penoxsulam, 18 DAS	51.73	88.83	101.98	122	255	4.24	7.83
Florpyrauxifen-benzyl + cyhalofop-butyl, 12 DAS	50.13	90.07	93.11	138	290	4.50	2.17
Florpyrauxifen-benzyl + cyhalofop-butyl, 18 DAS	51.40	88.86	97.27	140	280	4.32	6.08
Cyhalofop-butyl *fb* Almix 18 DAS and 19 DAS	50.96	85.43	98.54	131	268	3.52	23.48
Bispyribac sodium, 18 DAS	52.56	90.46	93.66	134	271	3.40	26.09
Hand weeding, 20 and 40 DAS	50.96	91.53	103.98	145	325	4.60	-
Unweeded control	50.86	84.59	93.05	94	201	1.99	56.74
LSD (0.05)	**NS**	**NS**	**NS**	**NS**	**6.12**	**0.72**	**-**
SEm(±)	**-**	**-**	**-**	**-**	**2.05**	**0.24**	**-**

Table 4. Effect of pre-mix herbicide combinations on economics of rice cultivation per ha

Treatments	Total cost (Rs.)	Gross returns (Rs.)	Net returns (Rs.)	B:C ratio
Pendimethalin + penoxsulam, 5 DAS	58350	146430	88080	2.5
Pendimethalin + penoxsulam, 10 DAS	58350	142890	84540	2.4
Cyhalofop-butyl + penoxsulam, 12 DAS	59275	144660	85385	2.4
Cyhalofop-butyl + penoxsulam, 18 DAS	59275	140940	81665	2.3
Florpyrauxifen-benzyl + cyhalofop-butyl, 12 DAS	58694	148980	90286	2.5
Florpyrauxifen-benzyl + cyhalofop-butyl,18 DAS	58694	143520	84826	2.4
Cyhalofop-butyl *fb* Almix 18 DAS and 19 DAS	59871	117120	57249	1.9
Bispyribac sodium, 18 DAS	58415	113460	55045	1.9
Hand weeding, 20 and 40 DAS	82000	152220	70220	1.8
Unweeded control	55000	66390	11390	1.2

Among these various herbicides,florpyrauxifen-benzyl + cyhalofop-butyl when sprayed within an application window of 12 DAS and 18 DAS, was regarded the best.

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