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Efficacy of pre- and post-emergence ready-mix herbicides in rainfed lowland wet-seeded rice

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ABSTRACT

The experiment was conducted during *Kharif* (rainy) season of 2019 to assess comparative efficacy of low dose high efficiency herbicides in providing season-long weed control in direct wet-seeded rainfed lowland rice at Integrated Farming System Research Station (IFSRS), Karamana, Kerala. The rice yield reduction due to unmanaged weeds in unweeded control in rainfed lowland rice was estimated to be 59.75%. Rice grain yield obtained was 159.9% higher in bensulfuron-methyl + pretilachlor *fb* HW at 40 DAS (5.46 t/ha) compared to weedy check with a B: C ratio of 1.83 and was at par with penoxsulam + cyhalofop-butyl *fb* HW at 40 DAS (5.35 t/ha) with a B:C ratio of 1.77. Application of ready mix of either bensulfuron-methyl + pretilachlor 60 + 600 g/ha at 3 DAS or penoxsulam + cyhalofop-butyl 150 g/ha at 20 DAS both *fb* HW at 40 DAS was observed as the most effective weed management strategy in wet-seeded lowland rainfed rice.

Rice (*Oryza sativa* L.) is one of the most important cereal crops of the world and the total milled rice consumption was about 490 million tonnes in 2018 and projected to reach 550 million tonnes by 2030 and 590 million tonnes by 2040 (Bhandari 2019). Rice is cultivated over widely varying environments, such as rainfed upland, rainfed lowland and irrigated upland ecosystems. The productivity of rice in India is low due to pest, disease and weed infestation of which weeds pose a greater threat in direct-seeded rainfed rice. In Kerala, area under rice cultivation during 2018-19 was estimated to be 0.17 million hectares with a productivity of 2.55 t/ha (Anonymous 2019). In a study on rainfed lowland wet-seeded paddy in Kerala, Umkhulzum and Ameena (2019) reported that unchecked weed growth could cause a reduction of 81% in net income. As farmers are shifting from transplanted to direct-seeded rice due to shortage of labour and high labour wages, direct-seeding in lowlands during *Kharif* (rainy season) becomes a widely adopted system of rice cultivation especially in Kerala. Direct-seeding of rice excludes nursery and transplanting that in turn decreases labour requirement and cost of cultivation apart from minimizing crop growth period by 8-10 days (Prasad *et al.* 2016, Rao *et al.* 2017).

The factors affecting the crop yield losses due to weeds depend upon the rice establishment methods and associated environment (Rao *et al.* 2017). Weed infestation reduces the rice yields upto 62.6, 70.6 and 75.8% in transplanted, wet-seeded and dry-seeded rice, respectively (Singh *et al.* 2005). Competition due to weeds is more severe in direct-sown rice due to simultaneous emergence of rice and weed seedlings whereas in transplanted rice, aged transplanted rice seedlings are able to compete with weeds better (Saha 2008, Rao *et al.* 2017a). In wet direct-seeded rice, initial 15-60 days is considered as critical period of crop-weed competition during which the field should be weed free to reduce losses (Rao *et al.* 2017a). Among different weed management practices, hand weeding (HW) and herbicide application were found effective in wet-seeded rice. However, HW is not possible and feasible during the very initial stages as certain grassy weeds look similar to rice and cannot be identified and hand weeded at its 4-6 leaf stage. To evade this cumbersome process, various pre-emergence (PE), early post-emergence (PoE) applied broad-spectrum herbicides can be made use of and many of the low dose high efficiency herbicides recently available are reported to be more effective than conventional herbicides in wet-seeded rice (Umkhulzum *et al.* 2018). Bensulfuron-methyl + pretilachlor and pyrazo-sulfuron-ethyl are effective as pre- and early PoE herbicides to manage the initial weed flora in rice

(Arya and Ameena 2016). Bispyribac-sodium and penoxsulam + cyhalofop-butyl are PoE herbicides with broad-spectrum activity. Metsulfuron-methyl + chlorimuron-ethyl and ethoxysulfuron are effective in controlling broad-leaved weeds and sedges in rice (Gopinath and Kundu 2008, Umkhulzum *et al.* 2018). In this context, the present experiment was conducted.

The field experiment was conducted in the lowland rice fields of Integrated Farming System Research Station (IFSRS), Karamana, Thiruvananthapuram situated geographically at 8^0 47' N latitude and 76^0 96' E longitude. Crop was grown during *Kharif* (rainy) season extending from June to October 2019 and the mean rainfall during the crop growing season was 99.05 mm. The soil type was sandy clay loam, strongly acidic, low in available nitrogen (273.9 kg/ha), high in available phosphorus (38.8 kg/ha) and low in available potassium (238 kg/ha). For the past several years, rice was being cultivated in the experimental site. The red kernelled, with medium bold grains, high yielding (8-10 t/ha), medium duration (120-135 days) rice variety *Uma* (*MO-16*) extensively grown in Kerala was used in the experiment. Farmyard manure 5 t/ha was provided as basal dose of organic manure and nutrient schedule of 90:45:45 NPK kg/ha was followed as per Kerala Agricultural University (KAU) package of practices.

The experiment was laid out in a randomized block design with 8 treatments replicated thrice having individual plot size of 20 m^2. The PE herbicides were applied using 300 litre/ha spray solution and the post-emergence herbicides were applied using 500 litres/ha spray solution. The weed density (no./m^2) and biomass (g/m^2) were recorded by placing a quadrat of size 0.5 x 0.5 m at two spots in each treatment and average was worked out. B:C ratio was worked out by considering prevailing market price for paddy and the price for different inputs and farm operations were considered for cost of cultivation. Analysis of variance was done for the statistical analysis of data.

Effect on weeds

During the cropping season, a variety of grasses, sedges and broad-leaved (BLW) weeds occurred in the field. From the initial stages of crop emergence up to critical growth stages, BLWs dominated the rice field. Among BLWs, *Sphenoclea zeylanica* was predominant along with *Ludwigia parviflora, Bergia capensis, Lindernia rotundifolia, Alternanthera sessilis, Limnocharis flava* and *Monochoria vaginalis* while *Ludwigia parviflora* dominated during later stages. *Sphenoclea zeylanica* was the predominant BLW seen up to the first 2.5 to 3 months because of its persistent infestation during the past seasons. Saha and Rao (2010) also stated the domination of BLW population, especially *Sphenoclea zeylanica* under wet-seeded condition. Grasses like *Echinochloa colona*, *Leptochloa chinensis* and *Ischaemum rugosum* were seen from initial stages. *Oryza sativa f. spontanea* was observed from 60 DAS onwards due to the difficulty in identifying the weedy rice plants before flowering. Sedges commonly associated with the crop were *Fimbristylis miliacea, Cyperus difformis* and *Cyperus iria.*

Effect on weed density, biomass and weed control efficiency

At 15 DAS, PE herbicide bensulfuron-methyl + pretilachlor (60 + 600 g/ ha) at 3 DAS registered 94.59% reduction in weed density over unweeded control while early PoE herbicide pyrazosulfuron ethyl 25 g/ha at 6 DAS recorded 89.57% reduction in direct wet-seeded lowland rice (**Table 1**). Though puddling and wet-seeding provided a favourable condition for flourishing of weed flora during the initial weeks of wet-seeding, PE bensulfuron-methyl + pretilachlor and early PoE herbicide pyrazosulfuron-ethyl 25 g/ha could bring about significant reduction in weed density upto one month. Weed biomass was statistically reduced by bensulfuron-methyl + pretilachlor and pyrazosulfuron-ethyl for a month over other treatments as the effect of herbicides sprayed on 3^{rd} and 6^{th} day prolonged till 30 DAS. Umkhulzum and Ameena (2019) reported 98.35% decline in weed density in relation to weedy check at 15 DAS in bensulfuron-methyl + pretilachlor treated wet-seeded rice while Yakadri *et al.* (2016) observed reduction in weed biomass with pyrazosulfuron-ethyl 25 g/ha. Rest of the experimental plots reported higher weed densities at 15 DAS owing to non-treatment up to that stage.

At 45 and 60 DAS, ready mix of penoxsulam + cyhalofop-butyl (150 g/ha) at 20 DAS *fb* HW, registered lower weed biomass due to broad-spectrum weed control compared to bispyribac-sodium sprayed at the same time. Weed biomass was 88.97 and 62.97% lower in PoE ready-mix herbicide treatments than the control HW twice. During the critical stages of crop weed competition at 30, 45 and 60 DAS, penoxsulam + cyhalofop-butyl *fb* HW at 40 DAS caused significant decline in weed density of 98.78, 94.64 and 96.01%, respectively. A steady increase in weed biomass of 12.20, 170.27, 306.10 and 400.84 g/m^2 at 15, 45 and 60 DAS, respectively was recorded in unweeded plots. This progressive increase in dry weight parallel to decline in weed density could be ascribed to higher dry matter contribution from individual weeds. At all crop growth stages, un-weeded plots also recorded in higher weed density of 345.33 at 15 DAS to 250.75 per m^2 at 60 DAS. The declining trend in weed density from the initial count to that at harvest could be attributed to the completion of life-cycle of some weeds and also could be due to the suppression of late emerged weeds by other competitive weeds.

Weed control efficiency indicates the relative efficacy of weed management treatments over weedy check. Amongst the weed management treatments, higher WCE of 99.28 and 96.23% was recorded in bensulfuron-methyl + pretilachlor upto 30 DAS, which was at par with pyrazosulfuron-ethyl with WCE of 96.18% (**Table 1**). Similar observations were made by Saha and Rao (2010). The pre-mix herbicide penoxsulam + cyhalofop-butyl applied at 20 DAS *fb* HW recorded superior weed control efficiencies from second month onwards due to effective suppression of sedges, grasses and BLWs during initial stages of crop growth followed by manual weeding at late emerging weeds.

Growth and yield

Bensulfuron-methyl + pretilachlor at 3 DAS *fb* HW at 40 DAS recorded 159.9% increase in rice grain yield over unweeded control and at par with penoxsulam + cyhalofop-butyl *fb* HW at 40 DAS, which recorded 154.8% gain in yield **(Table 2)** due to extended period of effective weed control at critical growth stages of the crop that helped the crop to utilize the inputs effectively resulting in better growth. Rice straw yield followed similar trend. Yadav *et al.* (2018) also observed superior rice yield similar to weed free with penoxsulam + cyhalofop 135 g/ha or 150 g/ha. Minimum grain and straw yields were recorded under weedy check due to greater weed infestation and weed biomass. Unrestricted weed growth led to 59.75% grain yield and 39.14% straw yield reduction compared with the hand weeding twice practice due to the lesser crop stand establishment and greater weed competition.

Weed index

Weed index (WI) is a parameter to describe yield loss occurred due to weed infestation in comparison with weed free plots. Negative or superior weed index was registered with ready mix herbicides bensulfuron-methyl + pretilachlor (-5.14%) and penoxsulam + cyhalofop-butyl (-2.96%) than HW twice indicating their greater efficacy in managing weeds than HW. Even though manual weeding was effective, identifying weeds in initial growth stages in direct wet-seeded rice is an arduous task necessitating the need for a pre- or early PoE herbicide. Singh *et al.* (2008) stated the common flaws in HW such as weed regrowth and weed escape leading to its ineffectiveness.

Economics of cultivation

The adoption of any technology is found feasible and acceptable to farmers only if it is economically viable and hence the actual comparison between two performing treatments can be done based on economic viability. In the present study, bensulfuron-

Table 1. Effect of weed management practices on weed density, biomass and weed control efficiency of direct-seeded rainfed lowland rice at 15, 30, 45 and 60 DAS

Treatment	Weed density (no./ m^2)				Weed biomass (g/m^2)				Weed control efficiency (%)			
	15 DAS	30 DAS	45 DAS	60 DAS	15 DAS	30 DAS	45 DAS	60 DAS	15 DAS	30 DAS	45 DAS	60 DAS
Bensulfuron-methyl + pretilachlor 60 + 600 g/ha at 3 DAS *fb* HW at 40 DAS	18.67	24.00	60.33	60.00	0.08	6.4	15.57	22.49	99.28	96.22	94.92	94.39
	(4.43)	(4.99)	(7.82)	(7.80)	(1.04)	(2.71)	(4.07)	(4.84)	(10.01)	(9.86)	(9.79)	(9.77)
Pyrazosulfuron-ethyl 25 g/ha at 6 DAS *fb* HW at 40 DAS	36.00	36.67	77.67	62.67	0.22	8.48	19.88	27.64	98.16	95.02	93.26	93.08
	(6.08)	(6.13)	(8.86)	(7.97)	(1.11)	(3.08)	(4.56)	(5.35)	(9.96)	(9.80)	(9.71)	(9.70)
Bispyribac-sodium 25 g/ha at 20 DAS *fb* HW at 40 DAS	272.00	13.33	45.33	44.00	10.17	14.25	7.87	22.23	16.78	91.62	97.42	94.46
	(16.52)	(3.78)	(6.80)	(6.68)	(3.34)	(3.90)	(2.98)	(4.82)	(4.14)	(9.62)	(9.21)	(9.77)
Penoxsulam + cyhalofop-p-butyl 150 g/ha at 20 DAS *fb* HW at 35- 40 DAS	291.33	4.00	14.67	10.00	9.87	10.94	1.35	4.61	18.50	93.55	99.54	98.85
	(17.09)	(2.24)	(3.95)	(3.31)	(3.29)	(3.45)	(1.53)	(2.37)	(4.32)	(9.72)	(10.03)	(9.99)
Metsulfuron-methyl + chlorimuron-ethyl 4 g/ha at 20 DAS *fb* HW at 40 DAS	281.00	8.00	18.67	23.00	9.94	11.66	3.12	10.28	18.49	93.13	98.98	97.22
	(16.78)	(2.95)	(4.41)	(4.84)	(3.31)	(3.56)	(2.03)	(3.31)	(4.41)	(9.70)	(10.00)	(9.91)
Ethoxysulfuron 15 g/ha at 20 DAS *fb* HW at 40 DAS	279.33	12.00	42.00	37.83	10.30	15.93	8.39	15.99	15.62	90.86	97.25	96.01
	(16.66)	(3.58)	(6.55)	(6.23)	(3.36)	(4.07)	(3.06)	(4.12)	(4.05)	(9.58)	(9.91)	(9.85)
Hand weeding at 20 and 40 DAS	256.33	13.33	61.00	28.67	10.40	7.09	12.24	12.45	14.78	95.82	96.01	96.88
	(15.93)	(3.78)	(7.84)	(5.44)	(3.37)	(2.84)	(3.62)	(3.67)	(3.95)	(9.84)	(9.85)	(9.89)
Weedy check (un-weeded control)	345.33	257.00	273.6	250.75	12.20	170.27	306.10	400.84	0.00	0.00	0.00	0.00
	(18.55)	(16.06)	(16.57)	(15.84)	(3.63)	(13.08)	(17.52)	(20.04)	(1.00)	(1.00)	(1.00)	(1.00)
LSD (p=0.05)	2.191	0.796	0.557	0.918	0.468	0.275	0.259	0.187	1.116	0.05	0.027	0.033

The data were subjected to square root transformation $\sqrt{x+0.5}$ and transformed values are given in parentheses; DAS: Days after seeding; *fb*: Followed by; HW: Hand weeding

Table 2. Effect of weed management treatments on yield and economics of direct-seeded rainfed lowland rice

Treatment	Rice grain yield (t/ha)	Rice straw yield (t/ha)	Harvest index	Weed index (%)	Gross income (x10^3 Rs/ha)	Net income (x10^3 Rs/ha)	B:C ratio
Bensulfuron-methyl + pretilachlor 60 + 600 g/ha at 3 DAS *fb* HW at 40 DAS	5.46	7.71	0.42	-5.14	164.15	74.32	1.83
Pyrazosulfuron-ethyl 25 g/ha at 6 DAS *fb* HW at 40 DAS	4.60	6.71	0.41	8.98	139.39	51.09	1.58
Bispyribac-sodium 25 g/ha at 20 DAS *fb* HW at 40 DAS	4.37	6.56	0.40	15.95	133.34	43.62	1.49
Penoxsulam + cyhalofop-p-butyl 150 g/ha at 20 DAS *fb* HW at 35-40 DAS	5.35	7.65	0.42	-2.96	161.38	70.51	1.77
Metsulfuron-ethyl + chlorimuron-ethyl 4 g/ha at 20 DAS *fb* HW at 40 DAS	5.09	7.34	0.41	2.18	153.79	65.27	1.74
Ethoxysulfuron 15 g/ha at 20 DAS *fb* HW at 40 DAS	4.75	6.83	0.41	8.75	143.39	55.41	1.63
Hand weeding at 20 and 40 DAS	5.20	7.18	0.42	0.00	155.59	52.19	1.50
Weedy check (un-weeded control)	2.10	4.69	0.31	59.75	71.79	-1.77	0.97
LSD (p=0.05)	0.216	0.468	0.025	5.892	-	-	-

methyl + pretilachlor *fb* HW fetched higher gross income (₹ 1,64,151/ha), net income (₹ 74,320/ha), and B:C ratio (1.83) because of superior grain and straw yield along with lesser herbicide cost. Despite higher herbicide cost, penoxsulam + cyhalofop-butyl registered the next best returns and BC ratio of 1.77. Eventhough, HW was efficient, herbicidal treatment was simple, economical, time and labour saving than manual weeding. Gross income (₹ 1,55,590/ha), net income (₹ 52,186/ha), and B: C ratio (1.50) obtained in manual weeding was lesser due to higher wage rates. Thus, application of ready-mixture of herbicides either PE bensulfuron-methyl + pretilachlor at 3 DAS or PoE penoxsulam + cyhalofop-butyl at 20DAS both *fb* HW at 40 DAS could be suggested as a practicable option for effective and season long weed management in rainfed lowland direct wet-seeded rice.

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