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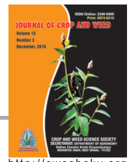

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Influence of weed management practices on weed flora, crop yield and nutrient uptake in direct seeded rainfed lowland rice

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ABSTRACT

An investigation was conducted at IFSRS, Karamana, Thiruvananthapuram during kharif 2019 to study the influence of weed management options on crop nutrient uptake and weed nutrient removal in direct seeded rainfed lowland rice. The investigation was conducted in randomized block design with eight treatments comprising of application of pre, early-post and post-emergent herbicides followed by (fb) hand weeding (HW) along with two controls (weed-free check and unweeded control) evaluated in three replications. Amongst the weed management options tested, the least weed dry weight during the critical growth stages and nutrient removal was recorded by penoxsulam+cyhalofop butyl 6% OD at 150 g ha^{-1} at 20 days after sowing (DAS) fb HW at 40DAS and at par with bensulfuronmethyl+pretilachlor @ 60+600 g ha^{-1} at 3DAS fb HW at 40DAS. Use of bensulfuronmethyl+pretilachlor @60+600 g ha^{-1} at 3 DAS fb HW at 40DAS maintained higher weed control efficiency allthrough the growth period and the NPK removal by weeds was limited to only one tenth of that registered in unweeded control. The ready-mix herbicides bensulfuronmethyl+pretilachlor (at 3 DAS) and penoxsulam+cyhalofop butyl (at 20DAS) each fb HW at 40DAS provided a minimal weed presence at the critical period and resulted in superior grain yields (5461and 5355 kg ha^{-1}, respectively),dry matter production (13.17 and 13t ha^{-1},respectively,) crop NPK uptake and weed NPK removal in direct seeded rainfed lowland rice.

***Keywords*:** Direct seeded lowland rice, herbicide mixtures, nutrient removal, nutrient uptake, weed dry weight, yield

More than two-third of the Indian population depends on rice as a major food and it holds a vital role in Indian economy as well as a major asset for food security (Mahajan *et al*., 2017). Productivity of direct seeded rice is lower which can be greatly attributed to the major biological hindrance *viz*., weeds which exert a greater competition in direct seeding. Besides yield reduction, they also remove 20-40 kg nitrogen, 0.8-15 kg phosphorus and 20-40 kg potassium per ha compared to weed free plot (Das *et al*., 2012). Even though manual weeding is effective, it is uneconomical because of high labour wages due to industrialization and urbanization. Also, manual weeding during initial stages is impractical in direct seeded rice due to the difficulty in identifying the grass weeds. Among the different weed control methods, management through herbicides plays a significant role in the era of modern agriculture (Singh *et al.,* 2017). For controlling diverse flora of weeds that come up during initial and later stages, various pre-emergence, early post-emergence and post-emergence broad-spectrum herbicides can be made use of. However, continuous application of same herbicides such as anilofos and butachlor in rice, led to a shift in weed flora to sedges such as *Scirpus sp*., *Cyperus sp., Eleocharis sp., Fimbristylis sp*. and *Caesulia auxillaris* (Chauhan *et al*., 2014). Rotating herbicides and use of appropriate mixtures are two key approaches to suppress the weed floral shift and resistance development to herbicide in weeds. In recent times, use of appropriate mixtures of herbicide either ready or tank mix is getting enhanced use as they are able to manage complex weed flora. In this background, the present investigation was undertaken to assess the effect of pre, early-post and post-emergence herbicides including herbicide mixtures on yield and crop nutrient uptake of direct seeded rice and consequent weed nutrient removal.

Field trial was undertaken in the 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) during *kharif* season extending from June to October 2019. The mean rainfall during the crop growing season was 99.05cm with temperature ranging from 23^0C to 32^0C.The experiment was laid out in randomized block design (RBD) with 8 treatments replicated thrice. The weed control treatments included application of pre, early post-emergence or post-emergence herbicides including ready mix herbicide combinations applied at 3,6 and 20 days after sowing (DAS) respectively followed by (fb) a hand weeding (HW). The treatments were T_1: bensulfuron methyl+pretilachlor @ 60+600 g ha^{-1} at 3DAS, T_2: pyrazosulfuron ethyl @ 25g ha^{-1}at 6 DAS, T_3: bispyribac sodium @ 25 g ha^{-1}at 20DAS, T_4: penoxsulam + cyhalofop butyl 6% OD @ 150 g ha^{-1} at 20DAS, T_5: metsulfuron methyl + chlorimuron ethyl @ 4g ha^{-1} at

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20DAS, T_6: ethoxysulfuron @ 15 g ha^{-1} at 20DAS, T_7:HW at 20 and 40DAS, T_8**:** weedy check (unweeded control) and the treatments T_1 to T_6 were fb HW at 40DAS. The soil texture of the experimental field was in the textural class of sandy clay loam which was low in available N, high in available P and medium in available K. The rice variety *Uma* (MO-16) extensively grown in Kerala was used in this experiment which is a red kernelled, high yielding, dwarf statured, medium tillering, non-lodging, medium duration (120-135 days) variety. The crop was supplied with farmyard manure @5 t ha^{-1} and NPK @ 90: 45: 45 kg ha^{-1}. Full dose of phosphorus and half each of nitrogen and potassium were supplied before sowing and remaining dose of N and K was applied at panicle initiation. Lime was applied @ 600 kg ha^{-1}.The pre-germinated seeds were broadcasted in puddled field adopting a seed rate of 80 kg ha^{-1}.

Weed management options were followed according to the treatments framed for the field experiment. The quantity of spray volume utilized was 500 L ha^{-1}. Manually operated knapsack sprayer was used for herbicide spraying. Pre-emergence, early post-emergence and post-emergence herbicide application were done at 3, 6 and 20 DAS, respectively fb hand weeding at 40 DAS. In weed free check, hand weeding was done at 20 and 40 DAS and weedy check plot maintained devoid of weed control practices. Periodical observations on dry weight of weeds were recorded at 15, 30, 45 and 60 DAS. Weeds within 50x50 cm sized quadrat that was positioned at random in three different places in each plot were utilized for subsequent observations. For weed dry weight, weed samples were uprooted, cleaned and oven dried till constant weight was obtained at 70 ±5^{0}C temperature, weighed and expressed in g m^{-2}. To estimate NPK content in plant sample, Microkjeldahl method, Vanadomoly dophosphoric yellow colorimetric method and Flame photometric method were used respectively (Jackson, 1958).

The nutrient removal of weed was estimated by multiplying the weed dry weight ha^{-1} with respective nutrient content and expressed in kg ha^{-1}. Grains obtained were dried to 13 per cent moisture content, weighed and similarly the straw obtained was sundried separately to a constant weight that combinedly indicated the dry matter production (DMP) and denoted in kg ha^{-1}. Nutrient uptake by the crop was computed by multiplying DMP with its nutrient content and expressed in kg ha^{-1}. Recorded data were tabulated and analysed using ANOVA applicable to RBD formulated by Cochran and Cox (1965).

The results on the influence of weed management options on total weed dry weight in direct seeded lowland rice at various stages *viz*. 15, 30, 45, and 60 DAS are represented in Table 1. Dry weight of weed plants in unit area differed with growth stages of crop and weed management treatments experimented.The weed dry weight was lowest in the ready mix pre-emergent herbicide bensulfuronmethyl+pretilachlor (T_1) at 15 and 30 DAS (0.08 and 6.41 g m^{-2}) and was statistically on a par with early post-emergence application of pyrazosulfuronethyl (T_2) (0.22 and 8.48 g m^{-2}). The effect of these pre and early post-emergent herbicides sprayed on the third and sixth day prolonged till 30 DAS which might be due to its broad-spectrum activity in controlling all categories of seed propagated weeds right at its germination stage. Arya and Ameena (2016) reported that bensulfuronmethyl + pretilachlor @ 60+600 g ha^{-1} and pyrazosulfuron ethyl @ 25g ha^{-1} were promising broad spectrum herbicides for early season control of weeds in semi-dry rice.

At 45 and 60 DAS, the ready mix post emergent herbicide penoxsulam+cyhalofopbutyl (T4) was significantly higher to all of the treatments (1.35 and 4.61 g m^{-2}) which might be due to superior control of grasses, sedges and BLW's by the post emergence application fb HW at 40DAS resulting in lesser weed dry weights. Yadav *et al*. (2018) realised better control of grasses, BLWs and sedges in transplanted rice with the ready mix penoxsulam+cyhalofop butyl @135g ha^{-1} applied at 15-20 DAT (days after transplanting). The dry weight reported by HW plot was high compared to the ready-mix herbicides (T_1 and T_4) which might be due to weed escape and easy regrowth in manually weeded plots that reduced its effectiveness and is in accordance with Singh *et al.* (2008). A steady progression in dry weights was recorded in unweeded plots from 15 to 60 DAS with dry weights of 12.20, 170.27, 306.10 and 400.84 g m^{-2} respectively.

The weed nutrient removal was noticed to be influenced by the weed management options followed (Table 1).N, P and K removal was lowest in penoxsulam + cyhalofop butyl fb HW (T_4) plot with 4.62, 0.34 and 5.51 kg ha^{-1} respectively and was statistically on a par with T_1 and T_5. The ready-mix herbicide combinations recorded minimum NPK removal and to be precise only one tenth of N, P and K removal registered in weedy check in comparison to other treatments. This could possibly be due to the poor weed dry matter build up by broad spectrum of weed control by herbicide at initial stages that was sustained by hand weeding at later stages. Application of ready-mix herbicide combinations with a follow-upmanual weeding resulted in 89.26, 88.96 and 88.58 per cent reduction in N, P and K removal respectively compared to weedy check. Maity and Mukherjee (2008) opined that weed management

Table 1: Effect of weed management options on weed dry weight, weed control efficiency and nutrient removal in direct seeded rainfed lowland rice

Treatments	Weed dry weight (gm^{-2})				Weed control efficiency (%)				Nutrient removal by weeds (kg ha^{-1})		
	15 DAS	30 DAS	45 DAS	60 DAS	15 DAS	30 DAS	45 DAS	60 DAS	N	P	K
T_1	0.08 (1.04)	6.4 (2.71)	15.57 (4.07)	22.49 (4.84)	99.28 (10.01)	96.22 (9.86)	94.92 (9.79)	94.39 (9.77)	4.86	0.37	6.23
T_2	0.22 (1.11)	8.48 (3.08)	19.88 (4.56)	27.64 (5.35)	98.16 (9.96)	95.02 (9.80)	93.26 (9.71)	93.08 (9.70)	7.38	0.55	8.71
T_3	10.17 (3.34)	14.25 (3.90)	7.87 (2.98)	22.23 (4.82)	16.78 (4.14)	91.62 (9.62)	97.42 (9.21)	94.46 (9.77)	9.44	0.74	11.01
T_4	9.87 (3.29)	10.94 (3.45)	1.35 (1.53)	4.61 (2.37)	18.50 (4.32)	93.55 (9.72)	99.54 (10.03)	98.85 (9.99)	4.62	0.34	5.51
T_5	9.94 (3.31)	11.66 (3.56)	3.12 (2.03)	10.28 (3.31)	18.49 (4.41)	93.13 (9.70)	98.98 (10.00)	97.22 (9.91)	5.97	0.50	7.39
T_6	10.30 (3.36)	15.93 (4.07)	8.39 (3.06)	15.99 (4.12)	15.62 (4.05)	90.86 (9.58)	97.25 (9.91)	96.01 (9.85)	8.31	0.69	9.58
T_7	10.40 (3.37)	7.09 (2.84)	12.24 (3.62)	12.45 (3.67)	14.78 (3.95)	95.82 (9.84)	96.01 (9.85)	96.88 (9.89)	12.01	1.02	15.21
T_8	12.20 (3.63)	170.27 (13.08)	306.10 (17.52)	400.84 (20.04)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	0.00 (1.00)	43.05	3.08	48.28
SEm (±)	**0.15**	**0.09**	**0.08**	**0.06**	**0.36**	**0.02**	**0.01**	**0.01**	**0.72**	**0.06**	**0.93**
LSD (0.05)	**0.468**	**0.275**	**0.259**	**0.187**	**1.116**	**0.05**	**0.027**	**0.033**	**2.213**	**0.175**	**2.852**

Note: T_1: bensulfuron methyl +pretilachlor 60 + 600 g ha^{-1}@3DAS fb HW at 40DAS; T_2: pyrazosulfuronethyl 25g ha^{-1}@ 6 DAS fb HW at 40DAS; T_3: bispyribac sodium 25 g ha^{-1} @ 20DAS fb HW at 40DAS; T_4: penoxsulam+cyhalofop p butyl 150 g ha^{-1}@ 20DAS fb HW at 40 DAS; T_5: metsulfuronethyl+chlorimuron ethyl 4g ha^{-1} @ 20 DAS fb HW at 40DAS; T_6: ethoxysulfuron 15g ha^{-1}@20 DAS fb HW at 40DAS; T_7: HW at 20 and 40DAS and T_8: weedy check (un-weeded control)
The data subjected to square root transformation and transformed values given in parentheses
DAS, Days after sowing; HW, Hand weeding

Table 2: Effect of weed management practices on dry matter, NPK uptake of crop and available soil nutrient status in direct seeded rainfed lowland rice

Treatments	Yield			NPK uptake by crop (kg ha^{-1})			Available soil nutrient status (kg ha^{-1})		
	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Dry matter (t ha^{-1})	N	P	K	N	P	K
T_1	5461	7710	13.17	157.44	10.72	373.29	197.23	33.74	194.86
T_2	4601	6715	11.32	134.74	8.34	303.54	167.84	32.64	142.99
T_3	4371	6562	10.93	126.21	9.08	293.5	134.51	30.77	138.43
T_4	5355	7646	13.00	154.53	10.24	366.01	188.86	34.37	188.53
T_5	5091	7339	12.37	145.80	8.92	346.72	176.20	33.42	170.05
T_6	4750	6829	11.58	137.46	9.32	309.77	147.05	31.55	135.07
T_7	5204	7177	12.38	146.70	10.14	333.78	159.59	33.58	178.90
T_8	2101	4692	6.79	79.63	4.28	180.19	117.78	29.84	139.44
SEm (±)	**70.75**	**152.99**	**0.18**	**6.51**	**0.38**	**8.61**	**19.28**	**1.04**	**16.10**
LSD (0.05)	**216.677**	**468.564**	**0.567**	**19.941**	**1.154**	**26.366**	**NS**	**NS**	**NS**

Note: T_1: bensulfuron methyl +pretilachlor 60 + 600 gha^{-1} @ 3 DAS fb HW at 40 DAS; T_2: pyrazosulfuron ethyl 25 gha^{-1} @ 6 DAS fb HW at 40DAS; T_3: bispyribac sodium 25gha^{-1}@ 20DAS fb HW at 40DAS; T_4: penoxsulam + cyhalofop p butyl 150 gha^{-1} @ 20 DAS fb HW at 40 DAS; T_5: metsulfuronethyl + chlorimuron ethyl 4 gha^{-1} @ 20 DAS fb HW at 40DAS; T_6: ethoxysulfuron15gha^{-1} @ 20 DAS fb HW at 40DAS; T_7: HW at 20 and 40DAS and T_8: weedy check (un-weeded control)
DAS, Days after sowing; HW, Hand weeding; NS, Non-significant

options reduced the nutrient depletion by weeds in direct seeded rice. Compared to herbicide use, higher nutrient removal by weeds was noticed in HW at 20 and 40 DAS (12.01, 1.02 and 15.21 kg ha^{-1} N, P and K respectively) which might be due to ineffectiveness of manual weeding and vigorous growth of weed plants. Weedy check plot resulted in highest nutrient removal of 43.05, 3.08 and 48.28 kg ha^{-1} N, Pand K respectively due to unrestricted weed proliferation in direct seeded rice. Manhas *et al.* (2012) reported nutrient removal of 53 kg N, 15.5 kg P and 58 kg K ha^{-1} compared to weed free plot.

The weed management practices displayed significant impact on grain yield and dry matter production of rice (Table 2) and the increase in grain and straw yield was about 61.52 and 39.14 per cent respectively when compared to unweeded control. Amongst the weed management practices, the ready-mix herbicides bensulfuronmethyl+pretilachlor applied at 3 DAS and penoxsulam + cyhalofop butyl at 20 DAS each fb HW at 40DAS recorded superior grain (5.46 and 5.35 t ha^{-1}) and straw yields (7.71and 7.65 t ha^{-1}) that led to higher dry matter production. These treatments provided almost a minimal weed presence at the period when the crop weed competition was critical to cause irreversible yield loss. This accords for the reports of Mubeen *et al.* (2014) which indicated that less crop-weed competition at critical growth stages augmented the rice grain yield. Sunil *et al.* (2011) reported that bensulfuronmethyl+pretilachlor @ 0.06 + 0.60 kg ha^{-1} at 3DAS fb intercultivation at 40DAS resulted in a greater amount of productive tillers per hill and higher test weight due to broad spectrum weed control. Yadav *et al.* (2018) stated that penoxsulam+cyhalofop @135 g ha^{-1} or 150 g ha^{-1} resulted in superior yield parameters similar to weed free treatment.

The nutrient uptake by rice crop was noticed to be influenced by the weed management options (Table 2). The NPK uptake by the crop could be increased by 49.42, 60.07 and 51.73 per cent respectively in contrast to weedy check plot by adopting weed control practices. Among the weed management options, T_1 reported higher crop nutrient uptake (157.44, 10.72 and 373.29 kg ha^{-1} NPK respectively) when equated to the remaining treatments and was at par with T_4. Pre-emergent or post emergent herbicide application with subsequent hand weeding at 40 DAS extended the period of effective weed control and helped the crop to utilize the inputs effectively for better growth and dry matter production resulting in lesser nutrient exhaustion by the weeds and greater nutrient uptake by rice. Nanjappa and Krishnamurthy (1980) testified an inverse relation between nutrient uptake by rice crop and nutrient depletion by weeds.

The weed management strategies failed to improve the nutrient status of soil after the harvest of rice. Available N, P and K status of soil after the experiment was unaffected by the weed management options tested. Before the experiment, available N was low in soil, available P at high and available K at medium rating. Compared to preliminary values, the available N, P and K content of the soil were noticeably reduced after the experimentation. Compared to the initial levels of available N, P and K in soil, unweeded plot was reported reduction of 40.0, 13.2 and 28.4 per cent, respectively.

It can be concluded that pre-emergent application of bensulfuronmethyl+pretilachlor@ 60+600 g ha^{-1} at 3DAS fb HW at 40DAS or penoxsulam + cyhalofop butyl 6 % OD @150g ha^{-1} at 20DAS fb HW at 40DAS could be adjudged as the best management optionin terms of lower weed dry weight and weed nutrient removal and higher grain yield and crop nutrient uptake in direct seeded rainfed lowland rice.

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