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Integrated management of rock bulrush (*Schoenoplectus juncoides*) in wet seeded rice

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ABSTRACT

Field experiment was conducted at the College of Agriculture, Vellayani during Rabi 2017to formulate anintegrated weed management strategy for managementofrock bulrush (Schoenoplectusjuncoides), an emerging sedge weed in the lowland paddy fields of Kerala. The treatments comprised of pre-emergenceherbicide,bensulfuron methyl + pretilachlor 60+600 g ha^{-1} at 4-7 DAS;early post emergent herbicides penoxsulam 22.5 g ha^{-1}, ethoxysulfuron 15 g ha^{-1},carfentrazone-ethyl 20 g ha^{-1}each at 15 DAS;and post emergent herbicides metsulfuron- methyl+ chlorimuron-ethyl 4 g ha^{-1}, 2, 4-D sodium salt 1 kg ha^{-1}each at 20 DAS and all herbicides were followed by (fb)hand weeding (HW)at 40 DAS.Ethoxysulfuron @ 15 g ha^{-1} at 15 DAS fb HW at 35- 40 DAS (T_3) was significantly superior with respect to productive tillers m^{-2}, number of grains panicle^{-1} and number of filled grains panicle^{-1}. Grain yield (5750 kg ha^{-1}) obtained from the plots treated with ethoxysulfuron 15 g ha^{-1} at 15 DAS fb HW was higher and on a par with penoxsulam @ 22.5 g ha^{-1} at 15 DAS fb HW (5500 kg ha^{-1}). Herbicides were effective in managing growth of bulrush during initial stages and the efficacy improved with a follow up HW at 35-40 DAS.Hand weeded plots (at 20 and 40 DAS)recorded lesser number of panicles m^{-2}, grains panicle^{-1} and filled grains panicle^{-1}compared to T_3 as Schoenoplectusjuncoides escaped hand weeding due to its needle like leaf morphology that made itsidentification difficult during initial stages (20 DAS)in the cropped fields. The study revealed that unchecked weed growth in wet seeded paddy with predominance of Schoenoplectusjuncoides could cause a reduction of 81% in net income (Rs 19,264 ha^{-1}) compared to the most economical weed management practice.

Keywords: Ethoxysulfuron, paddy, penoxsulam, rock bulrush, schoenoplectusjuncoides,sedges, wet direct seeded rice

Competition of direct seeded paddy tothe diverseweed species in field is reflected in its yield. In India, the percentage of yield loss recorded in transplanted and direct seeded paddy ranges from 12 - 69 % and 17 - 98 % respectively (Singh *et al*., 2011).Among the weed flora, sedges pose a greater threat to rice as they are usually perennial with underlying propagules that help in tiding over unfavourable climatic conditions. Rock bulrush (*Schoenoplectusjuncoides*), a sedge species belonging to Cyperaceae, problematic in the Asian countries has recently invaded the paddy fields of Kerala.It is anannual / perennial sedge with hollow stem and is found to grow copiously in the lowland paddy field and field bunds. Umkhulzum *et al*. (2018) reported that the weed hasan average height of 66.76 cm at maturity, vigorously tillering with an average tiller production of 19.6 tillers per plant, having fibrous roots growing to a mean depth of 17.76 cm with a dry weight of 0.99 g plant^{-1} and average biomass production of 0.96 t ha^{-1}.

IRRI (2017) included *Schoenoplectusjuncoides* as one among the twelve most troublesome weeds in the rice fields of South and South East Asia. It is found to grow aggressively throughout the growing period of paddy with lodged tillers carrying mature seeds aggravating the level of damage especially in broadcasted crop.Though manual weeding is the farmer's practice, it cannot be advocated as an effective strategy for managing rock bulrush, especially in wet-seeded broadcasted paddy owing to the failure in identifying the weed and also in removing the underground weed propagules. Pre or early post emergent herbicides are effective and easy-to-apply for early season weed control and if integrated wisely with manual weeding can become more economical. Hence, in the present investigation, application of pre-emergence, early-post emergence and post-emergence herbicides followed by hand weeding was tested for their effectiveness in controlling *Schoenoplectus juncoides* during wet seeding of rice.

MATERIALS AND METHODS

A field experiment was conducted during *Rabi* season (November 2017 to March 2018) in the lowland paddy field of Nemom block (8.4 ° N, 77.08 ° E and 28m above mean sea level) of Thiruvananthapuram, Kerala. In the experimental field, the soil texture was sandy clay loam with strongly acidic pH of 5.4 with normal electrical conductivity (0.47 dSm^{-1}) high organic carbon content (1.10%), low level of available nitrogen (275.97 kg ha^{-1}), high levels of available phosphorus (39.20 kg ha^{-1}) and available potassium (240 kg ha^{-1}). The layout of the experimental field was Randomized Block Design

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(RBD) with 8 treatments in three replications. The tested treatments were: bensulfuron methyl + pretilachlor @ 60+600 g ha^{-1} at 4-7 days after sowing (DAS) fb HW 40 DAS, penoxsulam@ 22.5 g ha^{-1} at 15 DAS fb HW 40 DAS, ethoxysulfuron 15 g ha^{-1} at 15 DAS fb HW 40 DAS, carfentrazone-ethyl 20 g ha^{-1} at 15 DAS fb HW 40 DAS, metsulfuron- methyl+ chlorimuron-ethyl 4 g ha^{-1} at 20 DAS fb HW 40 DAS, 2,4-D sodium salt 1 kg ha^{-1} at 20 DAS fb HW 40 DAS, HW twice at 20 and 40 DAS and un-weeded control. Pre-germinated seeds of paddy variety 'Sreyas'(MO-22) was broadcasted onto the puddled soil. FYM 5 t/ha and fertilizer schedule for medium duration rice (90:45:45 kg N:P_2O_5:K_2O ha^{-1}) was adopted as per Package of Practices (POP) recommendation of KAU (2016).Ten sample plants randomly chosen from the net plot of individual plots were tagged for taking relevant observations on yield. Recorded data were tabulated and subjected to Analysis of Variance (ANOVA) applicable to RBD and the least significantdifference (LSD) values at 5% level of significance were calculated to test significant differencebetween treatment means.

RESULTS AND DISCUSSION

Effect of weed management practices on weed densityand weed dry weight

Weed density refers to the number of weeds per unit area. At 15 DAS, density of *Schoenoplectusjuncoides* was the lowest (0.67 m^{-2}) in bensulfuron methyl + pretilachlor @ 60+ 600 g ha^{-1} at 4-7 DAS(T_1) with 98.35 per cent decline in weed count in relation to weedy check. This could be attributed to its pre-emergence spray at 4-7 day after wet seeding. All other plots recorded higher densities of rock bulrush at that stage due to absence of any treatment application at that period of observation. Application of post-emergence herbicides at 15 and 20 DAS resulted in lower densities of rock bulrush at 30 DAS upon comparison with weedy check. Tall, robust growth of plants with ethoxysulfuron spray could effectively suppress weed growth. The duration of weed control got extended when application of ethoxysulfuron@ 15 g ha^{-1} at 15 DAS was coupledwithHW 35-40 DAS. Hence the combination of early post-emergence application of ethoxysulfuron and HW could give effective control ofrock bulrush throughout the crop growing season. Ethoxysulfuron has been proved especially good for controlling the sedges belonging to *Scirpus*sp. (Sondhia and Dixit, 2012). Lowerdry weight of weeds at 15 DAS obtained in bensulfuron methyl + pretilachlor @ 60+600 g ha^{-1} at 4-7 DAS is due to lesser weed count per unit area in the plots treated.Earlier, lower weed density and dry weight were recorded in rice fields treated with bensulfuron methyl @ 60 g + pretilachlor @ 600 g ha^{-1} by Teja *et al*. (2015).Weed dry weight recorded at 45 and 60 DAS in plots treated with ethoxysulfuronfb HW at 35-40 DAS were 83.75 and 34.17 per cent lesser than the plots hand weeded twice at 20 and 40 DAS. This indicated that both ethoxysulfuron and penoxsulamfb HW were more effective in controlling rock bulrush thanHW twice during the critical period of crop-weed competition (20 and 40 DAS).

Effect of weed management practices on growth and yield attributes of rice

Apart from the major weed of study *Schoenoplectus juncoides*, thick growth of grasses, sedges and broad leaved weeds offered competition right from crop emergence and results of the study highlighted the need for a promising weed management strategy in wet seeded broadcasted paddy. Weed interference was observed at all growth stages of rice (Table 1), depriving the crop from taking up necessary resources required for optimum growth. Further, pre-emergence herbicides, post-emergence herbicides and hand weeding twice at 20 and 40 DAS were equally effective in increasing the crop height. Hand weeding at critical stages of crop-weed competition (20 and 40 DAS), managed the weeds effectively and had a positive effect on plant height at 60 DAS. Lower crop-weed competition during critical stages would lead to robust growth of crops and offer competitive advantage in terms of optimal use of nutrients, water, sunlight and space. At harvest, penoxsulam @ 22.5 g ha^{-1} at 15 DAS fb HW at 35-40 DAS recorded taller rice plants (104.67cm). Netam *et al*. (2018) also reported the superiority of penoxsulam @ 22.5 g ha^{-1}fb single HW at 35 DAS/ DAT in relation to the height of rice. It was found that herbicides were effective during initial stages and the efficacy improved with a follow up HW at 35-40 DAS. Unchecked weed population in the weedy check plots conferred6 per cent reduction in crop height. Sahu (2016) reported 14.25 per cent height reduction of rice plants in the un-weeded plots of direct seeded lowland paddy in comparison with hand weeded plots.

Though plant height decides the competence of crop, final yield is determined by the yield attributes like productive tillers m^{-2}, number of grains $panicle^{-1}$, number of filled grains $panicle^{-1}$, sterility percentage and thousand grain weight. Ethoxysulfuron @ 15 g ha^{-1} at 15 DAS fb HWat 35- 40 DAS (T_3) was significantly superior with respect to productive tillers m^{-2}, number of grains $panicle^{-1}$ and number of filled grains $panicle^{-1}$. Early post-emergence spray of the herbicide, when given a follow up of HW at 35-40 DAS was found to prolong the effective period of weed control and helped in maintaining the weedsbeloweconomic threshold level especially at critical stages of crop growth. Saini and

Table 1:Effect of weed management practices weed count and weed dry weight at15, 30, 45 and 60 DAS

Treatments	Weed density (number m^{-2})				Weed dry weight (g m^{-2})			
	15 DAS	30 DAS	45 DAS	60 DAS	15 DAS	30 DAS	45 DAS	60 DAS
T_1: bensulfuron methyl + pretilachlor @ 60+600 g ha^{-1} at 4-7 DAS fb HW at 35-40 DAS	0.67 (1.24)	3.58 (2.01)	6.81 (2.79)	10.49 (3.39)	0.08 (1.04)	1.42 (1.51)	2.87 (1.97)	4.04 (2.25)
T_2: penoxsulam @ 22.5 g ha^{-1} at 15 DAS fb HW at 35-40 DAS	31.40 (5.69)	3.59 (2.14)	2.92 (1.97)	4.22 (2.28)	10.62 (3.41)	1.58 (1.60)	0.66 (1.28)	1.99 (1.73)
T_3: ethoxysulfuron @15 g ha^{-1} at 15 DAS fb HW at 35-40 DAS	34.22 (5.92)	5.96 (2.64)	2.09 (1.69)	3.15 (2.04)	13.17 (3.76)	1.56 (1.59)	0.13 (1.06)	1.83 (1.68)
T_4: carfentrazone-ethyl @ 20 g ha^{-1} at 15 DAS fb HW at 35-40 DAS	22.55 (4.84)	4.04 (2.24)	5.04 (2.44)	7.43 (2.90)	11.79 (3.58)	1.25 (1.49)	1.59 (1.61)	4.03 (2.24)
T_5: metsulfuron methyl+ chlorimuron ethyl @ 4 g ha^{-1} at 20 DAS fb HW at 35-40 DAS	32.33 (5.75)	6.78 (2.78)	7.21 (2.86)	9.34 (3.22)	11.99 (3.60)	2.38 (1.84)	2.80 (1.95)	6.33 (2.71)
T_6: 2,4-D sodium salt @1 kg ha^{-1} at 20 DAS fb HW at 35-40 DAS	28.89 (5.43)	8.22 (3.04)	9.79 (3.28)	7.53 (2.92)	12.94 (3.73)	2.26 (1.78)	1.85 (1.69)	3.55 (2.13)
T_7: HW at 20 and 40 DAS	28.56 (5.24)	5.19 (2.47)	3.14 (2.03)	9.88 (3.29)	11.98 (3.60)	1.76 (1.65)	0.80 (1.32)	2.78 (1.94)
T_8: weedy check	40.55 (6.46)	53.57 (7.39)	62.34 (7.96)	64.11 (8.07)	14.11 (3.89)	35.47 (6.01)	70.11 (8.41)	96.05 (9.84)
SEm (±)	**0.47**	**0.21**	**0.18**	**0.09**	**0.07**	**0.20**	**0.15**	**0.13**
LSD (0.05)	**1.450**	**0.640**	**0.550**	**0.270**	**0.201**	**0.624**	**0.460**	**0.405**

The data were subjected to square root transformation "(x + 0.5) and transformed values are given in paranthesis

Table 2: Effect of weed management practices on growth,yield attributes and economics of rice

Treatments	Plant height of rice (cm)			Productive tillers m^{-2}	Number of grains $panicle^{-1}$	Filled grains $panicle^{-1}$	Sterility percentage	Thousand grain weight (g)	Grain yield (kg ha^{-1})	Straw yield (kg ha^{-1})	Harvest Index	Gross income (Rs ha^{-1})	Net income (Rs ha^{-1})	B: C ratio
	30 DAS	60 DAS	At harvest											
T_1 : bensulfuron methyl + pretilachlor @ 60+600 g ha^{-1} at 4-7 DAS fb HW at 35-40 DAS	42.92	66.86	102.82	317.00	100.36	85.45	14.87	27.60	5050.00	8678.33	0.368	159542	77141	1.93
T_2: penoxsulam @ 22.5 g ha^{-1} at 15 DAS fb HW at 35-40 DAS	41.00	65.11	104.67	318.33	100.79	86.09	14.59	28.87	5500.67	9201.67	0.374	172524	90703	2.11
T_3: ethoxysulfuron @15 g ha^{-1} at 15 DAS fb HW at 35-40 DAS	42.19	69.56	104.59	382.00	134.27	115.85	13.65	28.97	5750.00	9955.00	0.366	182025	101475	2.26
T_4: carfentrazone-ethyl @ 20 g ha^{-1} at 15 DAS fb HW at 35-40 DAS	42.64	69.86	102.57	337.00	105.67	90.87	13.92	28.27	5061.33	9208.67	0.356	162454	81878	2.02
T_5: metsulfuron methyl+ chlorimuron ethyl @ 4 g ha^{-1} at 20 DAS fb HW at 35-40 DAS	46.61	65.97	100.86	331.67	107.65	92.40	14.16	27.03	4310.67	8909.67	0.327	143694	62730	1.77
T_6: 2,4-D sodium salt @1 kg ha^{-1} at 20 DAS fb HW at 35-40 DAS	42.72	67.94	101.92	352.33	116.72	98.19	15.79	29.17	5148.67	9847.00	0.343	167654	87388	2.09
T_7: HW at 20 and 40 DAS	40.36	70.51	104.46	354.33	115.71	99.19	14.18	29.17	5432.67	9735.00	0.358	173626	83680	1.93
T_8: weedy check	43.69	62.47	98.83	308.67	97.37	78.82	18.94	28.13	2750.00	5692.00	0.325	91710	19264	1.26
SEm(±)	**1.29**	**0.86**	**1.09**	**8.57**	**2.83**	**1.75**	**1.51**	**1.02**	**94.24**	**309.78**	**0.009**	-	-	-
LSD(0.05)	**NS**	**2.621**	**3.334**	**26.251**	**8.654**	**5.348**	**NS**	**NS**	**288.603**	**948.727**	**0.0280**	-	-	-

Angiras (2002) also reported the potency of early post-emergence spraying of ethoxysulfuron @ 20 and 30 g ha^{-1} in managing BLW and sedges in wet seeded system of paddy. Hand weeded plots recorded 7.2, 13.8 and 14.4 per cent lesser number of panicles m^{-2}, grains $panicle^{-1}$ and filled grains $panicle^{-1}$compared to T_3. This could be because *Schoenoplectusjuncoides* escaped hand weeding due to its needle like leaf morphology that made it difficult to identify the weed during initial stages (20 DAS)in the cropped fields. Hence, the use of herbicides could be encouraged for effective management of rock bulrush.Uncontrolled weeds in theweedy check plots markedly reduced the number of panicles m^{-2}, grains $panicle^{-1}$ and filled grains $panicle^{-1}$ to the tune of 19.2, 27.5 and 32 per cent respectively, which is in conformity with the observations made by Singh (2012) in direct seeded rice, where 21.2 and 31 per cent reduction in panicles tillers m^{-2} and number of grains $panicle^{-1}$ respectively in unchecked weed growth.Lowest number of panicles m^{-2}(308.67) observed in weedy check was at par with T_1 (317), T_2(318.33) and T_5 (331.67).

Higher grain yield obtained in plot sprayed with ethoxysulfuron @ 15 g ha^{-1} at 15 DAS fb HW (5750 kg ha^{-1})was at par with penoxsulam@22.5 g ha^{-1} at 15 DAS fb HW(5500 kg ha^{-1}). Reddy *et al*. (2000) reported ethoxysulfuron @ 30 g ha^{-1}, as an effective herbicide against the sedge sp. *Schoenoplectussupinus*, *Cyperusdifformis* and *Cyperusiria* when applied at 10 DAT. The supremacy of ethoxysulfuron treated plots could be related to the productive $tillers^{-1}$, grains $panicle^{-1}$, filled grains $panicle^{-1}$and higher fertility percentage.Yield reduction recorded in hand weeded control was only 5.52 per cent (5432 kg ha^{-1}) in comparison with the superior treatment indicating the effectiveness of hand weeding. Mukherjee *et al*. (2008) also considered HW at critical stages (15 to 60 DAS) as effective, in managing weeds in wet seeding system of paddy with only 0.44 to 3 per cent decline in yield with respect to the best treatment. However, uncontrolled weed growth could cause a grain yield reduction of 52.2 and 49.4 per cent in comparison with ethoxysulfuron and hand weeding twice. Pandey (2009) also noticed lower grain yield in the plots with unchecked weed growth. Less panicles m^{-2}, grains $panicle^{-1}$and filled $grains^{-1}$ in conjunction with increased spikelet sterility would lead to decreased yields. Mukherjee *et al*. (2008) explained the need for maintaining weeds below the economic threshold levelin wet seeded rice from 15 to 60 DAS. Maintaining the field weed-free at critical stages of crop growth has a decisive role on grain yield.Thousand grain weight is a variety related trait which is not determined by the treatments. Mondal *et al*. (2005) observed the variation of thousand grain weight depending on the variety used when they compared 17 *Aman* rice cultivars in the transplanted system.

Higher straw yield was recorded by T_3(9955 kg ha^{-1}). All the treatments except bensulfuron methyl + pretilachlor, metsulfuron methyl + chlorimuron ethyl and weedy check, had a straw production at par with ethoxysulfuron @ 15 g ha^{-1}.Combination herbicides applied as pre-emergence and post-emergence were ineffective in increasing the straw yield. Straw yield could be related to the tiller number m^{-2}. Decline in straw yield by 42.8 per cent in the weedy check plots could be associated with the lower crop stand and tiller number. Also, lodging of rock bulrush resulted in the lodging of surrounding rice plants, which in turn reduced the plant stand in the un-weeded plot. Lower straw yield in un-weeded control was reported by Aryaand Ameena(2016) in semi-dry system of rice cultivation. Though grain and straw yield recorded were the highest in ethoxysulfuron@ 15 g ha^{-1}fb HW, proportion of economic yield out of the total biological yield was higher for penoxsulam. This could be due to the lower straw yield obtained in T_2.

Economics

Economically, ethoxysulfuron@ 15 g ha^{-1}fb HW is superior in terms of its gross income (Rs 1, 82,025 ha^{-1}), net income (Rs 1, 01,475 ha^{-1}) and B: C ratio (2.26). Grain yield obtained from penoxsulam@ 22.5 g ha^{-1}fb HW was higher (5500 kg ha^{-1}) next to T_3 registering a net income of Rs 90,703 $ha^{-1}$and B: C ratio of 2.11. Unchecked weed growthin wet seeded paddy with predominance of *Schoenoplectusjuncoides*caused a reduction of 81per cent in net income (Rs 19,264 ha^{-1}) compared to the most economical weed management practice.The integrated weed management strategy of spraying ethoxysulfuron @ 15g ha^{-1} or penoxsulam @ 22.5 g ha^{-1} at 15 DAS each fb HW at 35-40 DAS recorded superior grain yields and straw yields compared to hand weeding. However, considering the economics, ethoxysulfuron @15g ha^{-1} at 15 DAS fbHW at 35-40 DAS could be adjudged as the most effective strategy for the management of *Schoenoplectusjuncoides* in wet seeded rice.

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