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Comparative efficacy of herbicides against rock bulrush *Schoenoplectus juncoides* (Roxb.) Palla in wet-seeded rice

S. Fathima Umkhulzum, M. Ameena* and P. Shalini Pillai

Department of Agronomy, College of Agriculture, Vellayani, Kerala 695 522

**Email: drameenaubaid@gmail.com*

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ABSTRACT

Field experiment was conducted at the College of Agriculture, Vellayani during 2017- 2018 to assess the efficacies of pre-emergence, early post-emergence and post-emergence herbicides for managing rock bulrush *Schoenoplectus juncoides* (Roxb.) Palla, an emerging sedge weed in the lowland paddy fields of Kerala. A pre-emergence spray of bensulfuron-methyl + pretilachlor 60+ 600 g/ ha at 4-7 days after sowing (DAS) was effective till 30 DAS with 93.3% reduction in weed count. At 45 and 60 DAS, lower weed density (2.09 and 3.15 no./m^2, respectively) and weed dry weight (0.13 and 1.83 g/m^2, respectively) were recorded for ethoxysulfuron 15 g/ha at 15 DAS *fb* HW at 40 DAS. Higher weed control efficiencies of 99.8% and 98.1% were obtained in plots treated with ethoxysulfuron 15 g/ha at 15 DAS *fb* HW at 40 DAS during critical stages of crop-weed competition (45 and 30DAS). Penoxsulam 22.5 g/ha at 15 DAS and ethoxysulfuron 15 g/ha at 15 DAS both *fb* HW at 40 DAS were on a par at 45 and 60 DAS in terms of weed control efficiency (99.1% and 97.9%, respectively. The weed removal of N, P and K (8.61, 3.13 and 10.95 kg/ha, respectively) were also lower with ethoxysulfuron 15 g/ha at 15 DAS *fb* HW at 40 DAS. The study revealed that rock bulrush could be effectively controlled by ethoxysulfuron 15 g/ha or penoxsulam 22.5 g/ha both at 15 DAS *fb* HW at 40 DAS.

Wet seeded rice is infested with a composite weed flora comprising of grasses, sedges and broad-leaved weeds. Among the three weed groups, sedges pose a greater threat to rice (Satapathy *et al.* 2017) as they are usually perennial with underlying propagules that help in tiding over unfavourable climatic conditions. Rock bulrush *Schoenoplectus juncoides* (Roxb.) Palla, a sedge weed belonging to Cyperaceae, problematic in the Asian countries has recently invaded the paddy fields of Kerala. *Schoenoplectus juncoides* has been documented to occur globally in direct seeded lowland rice. IRRI (2017) included *S. juncoides* as one among the twelve most troublesome weeds in the rice fields of South and South-East Asia. Rock bulrush, annual / perennial sedge with hollow stem was found to grow copiously in the lowland paddy field, field bunds, and associated water channels. The weed was observed to grow to a height of 66.76 cm at maturity, vigorously tillering with an average tiller production of 19.6 tillers/plant and fibrous roots growing to a mean depth of 17.76 cm with a dry weight of 0.99 g/plant and average biomass production of 0.96 t/ha (Umkhulzum 2018).

Uncontrolled weeds reduce the grain yield by 61% in wet-direct seeded rice (Maity and Mukerjee 2008). Though manual weeding is the farmer's practice, it cannot be inculcated as an effective strategy for managing rock bulrush, especially in wet-seeded broadcasted paddy owing to the failure in removing the underground weed propagules. The use of herbicides can maintain the weed below its economic threshold limits, but continuous use of herbicides can induce resistance in weeds. Shultana *et al.* (2016) observed integrated use of pre-or post-emergence herbicides in conjunction with hand weeding as a better weed management strategy in wet- seeded rice. Use of new generation herbicides is an attractive option for weed management due to lower application rates and lower mammalian toxicity. In the present investigation, application of pre-emergence, early-post emergence and post-emergence herbicides followed by hand weeding, were tested for their effectiveness in controlling *S. juncoides* in wet- seeded rice.

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. Soil in the experimental field was sandy clay loam in texture, strongly acidic (pH 5.4) with normal electrical conductivity (0.47 dS/m) high organic carbon (1.10%), low available nitrogen (275.97 kg/ha), high available phosphorus (39.20 kg/ha) and high available potassium (240 kg/ha). The experiment was laid out in randomized block design (RBD) with 8 treatments and replicated thrice. The treatments were: bensulfuron methyl + pretilachlor 60 + 600 g/ ha at 4-7 days after sowing (DAS) followed by (*fb*) hand weeding (HW) at 40 DAS, penoxsulam 22.5 g/ ha at 15 DAS *fb* HW at 40 DAS, ethoxysulfuron 15 g/ha at 15 DAS *fb* HW at 40 DAS, carfentrazone-ethyl 20 g/ha at 15 DAS *fb* HW at 40 DAS, metsulfuron- methyl+ chlorimuron-ethyl 4 g/ha at 20 DAS *fb* HW at 40 DAS, 2,4-D sodium salt 1 kg/ ha at 20 DAS *fb* HW 40 DAS, HW twice at 20 and 40 DAS and weedy check. Pre-germinated seeds of rice 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) was adopted as per package of practices recommendation of KAU (2016). Weeds falling within the frame of 50 x 50 cm iron quadrant were collected at 15, 30, 45 and 60 DAS; counted and oven dried at 70 ± 5°C to a constant weight for taking the relevant observations on weeds. At maturity stage, weeds were uprooted and dried for nutrient analysis. Data requiring transformation were appropriately transformed and subjected to analysis of variance (ANOVA) applicable to randomized block design and the least significant difference (LSD) values at 5% level of significance were calculated to test significant difference between treatment means.

Weed flora

The weed spectra of the experimental field were associated with a multitude of weeds including grasses, sedges and broad-leaved weeds (BLW) with a clear dominance of sedges during the growing season (**Table 1**). At all stages of crop growth, rock bulrush (*S. juncoides*) co-occurred with the crop and dominated the field. *Fimbristylis miliacea*, *Isachne miliacea*, *Lindernia rotundifolia*, and *Ludwigia perennis* were also observed to infest the field throughout the crop life cycle. Broad-leaved weeds (BLW) were present at varying densities in the field, but did not dominate at any stage of the crop. The applied treatments were found to be effective in managing sedges and BLW during the cropping season, leaving behind grasses such as *Isachne miliacea* and *Digitaria sanguinalis*.

Effect on weed density

At 15 DAS, the density of *S. juncoides* was the lowest (0.67/m^2) in bensulfuron-methyl + pretilachlor 60 + 600 g/ha at 4-7 DAS with a reduction in weed count to the tune of 98.4% over weedy check which could be attributed to its pre-emergence spray at 4th day after wet-seeding. All other plots recorded higher densities of rock bulrush at 15 DAS due to the absence of any treatment application at that period of observation (**Table 2**). Effect of the pre-emergence spray of bensulfuron-methyl + pretilachlor 60 + 600 g/ha at 4-7 DAS lasted upto 30 DAS as evident from the reduction in weed density to 93.3%. Application of early post-emergence (15 DAS) and post-emergence herbicides (20 DAS) resulted in lower densities of rock bulrush at 30 DAS compared to weedy check. At the critical stages of the crop-weed competition in wet seeded rice (45 and 60 DAS) ethoxysulfuron 15 g/ha at 15 DAS *fb* HW at 35-40 DAS gave a considerable reduction in weed density. Son and Rutto (2002) observed ethoxysulfuron as an effective early post-emergence herbicide against

Table 1. Weed flora and relative density of weeds in the experimental field

Family	Scientific name	Common name	Relative density
Poaceae	*Isachne miliacea*	Blood grass	20.00
Poaceae	*Digitaria sanguinalis*	Crab grass	0.25
Cyperaceae	*Schoenoplectus juncoides*	Rock bulrush	72.00
	Fimbristylis miliacea	Globe finger rush	12.00
	Cyperus exaltatus	Tall flat sedge	1.00
	Cyperus haspan	Haspan flat sedge	0.25
	Cyperus difformis	Umbrella sedge	1.00
	Cyperus iria	Rice flat sedge	2.00
	Cyperus cyperoides	Pacific island flat sedge	0.25
Limnocharitaceae	*Limnocharis flava*	Water cabbage	3.00
Onagraceae	*Ludwigia perennis*	Water primrose	0.25
Scrophulariaceae	*Lindernia rotundifolia*	False pimpernel	2.00

Table 2. Effect of weed management practices on density of rock bulrush (no./m²) at 15, 30, 45 and 60 DAS

Treatment	15 DAS	30 DAS	45 DAS	60 DAS
Bensulfuron-methyl + pretilachlor 60+600 g/ha at 4-7 DAS *fb* HW at 40 DAS	0.67 (1.24)	3.58 (2.01)	6.81 (2.79)	10.49 (3.39)
Penoxsulam 22.5 g/ha at 15 DAS *fb* HW at 40 DAS	31.40 (5.69)	3.59 (2.14)	2.92 (1.97)	4.22 (2.28)
Ethoxysulfuron 15 g/ ha at 15 DAS *fb* HW at 40 DAS	34.22 (5.92)	5.96 (2.64)	2.09 (1.69)	3.15 (2.04)
Carfentrazone-ethyl 20 g/ha at 15 DAS *fb* HW at 40 DAS	22.55 (4.84)	4.04 (2.24)	5.04 (2.44)	7.43 (2.90)
Metsulfuron-methyl + chlorimuron ethyl 4 g/ha at 20 DAS *fb* HW at 40 DAS	32.33 (5.75)	6.78 (2.78)	7.21 (2.86)	9.34 (3.22)
2,4-D sodium salt 1 kg/ha at 20 DAS *fb* HW at 40 DAS	28.89 (5.43)	8.22 (3.04)	9.79 (3.28)	7.53 (2.92)
HW at 20 and 40 DAS	28.56 (5.24)	5.19 (2.47)	3.14 (2.03)	9.88 (3.29)
Weedy check	40.55 (6.46)	53.57 (7.39)	62.34 (7.96)	64.11 (8.07)
LSD(p=0.05)	1.450	0.640	0.550	0.270

The data were subjected to square root transformation ($\sqrt{x+0.5}$) and transformed values are given in parentheses

Table 3. Effect of weed management practices on weed dry weight (g/m²) at 15, 30, 45 and 60 DAS

Treatment	15 DAS	30 DAS	45 DAS	60 DAS
Bensulfuron-methyl + pretilachlor 60+600 g/ha at 4-7 DAS *fb* HW at 40 DAS	0.08 (1.04)	1.42 (1.51)	2.87 (1.97)	4.04 (2.25)
Penoxsulam 22.5 g/ha at 15 DAS *fb* HW at 40 DAS	10.62 (3.41)	1.58 (1.60)	0.66 (1.28)	1.99 (1.73)
Ethoxysulfuron 15 g/ha at 15 DAS *fb* HW at 40 DAS	13.17 (3.76)	1.56 (1.59)	0.13 (1.06)	1.83 (1.68)
Carfentrazone-ethyl 20 g/ha at 15 DAS *fb* HW at 40 DAS	11.79 (3.58)	1.25 (1.49)	1.59 (1.61)	4.03 (2.24)
Metsulfuron-methyl+ chlorimuron-ethyl 4 g/ha at 20 DAS *fb* HW at 40 DAS	11.99 (3.60)	2.38 (1.84)	2.80 (1.95)	6.33 (2.71)
2,4-D sodium salt 1 kg/ha at 20 DAS *fb* HW 40 DAS	12.94 (3.73)	2.26 (1.78)	1.85 (1.69)	3.55 (2.13)
HW at 20 and 40 DAS	11.98 (3.60)	1.76 (1.65)	0.80 (1.32)	2.78 (1.94)
Weedy check	14.11 (3.89)	35.47 (6.01)	70.11 (8.41)	96.05 (9.84)
LSD(p=0.05)	0.201	0.624	0.460	0.405

The data were subjected to square root transformation ($\sqrt{x+0.5}$) and transformed values are given in parentheses

sedges and BLW in cereals, especially rice. The duration of weed control got extended when the application of ethoxysulfuron 15 g/ha at 15 DAS was coupled with HW at 35-40 DAS. Hence the combination of the early post-emergence application of ethoxysulfuron and HW could give effective control of rock bulrush throughout the crop growing season. Ethoxysulfuron has been proved especially good for controlling the sedges belonging to *Scirpus* sp. (Sondhia and Dixit 2012).

Effect on weed dry weight

Bensulfuron- methyl + pretilachlor 60 + 600 g/ha at 4 DAS recorded lower dry weight of rock bulrush at 15 DAS due to lesser weed count in the plots treated (**Table 3**). In aerobic rice, Sunil *et al.* (2010) observed that the pre-emergence application of bensulfuron-methyl + pretilachlor 60 + 600 g/ha *fb* HW at 40 DAS was effective in reducing the weed count and dry weight. At 45 and 60 DAS, ethoxysulfuron *fb* HW recorded lower weed dry weights of 0.13 g/m² and 1.83 g/m² respectively. Weed dry weight recorded at 45 and 60 DAS in plots treated with ethoxysulfuron *fb* HW at 40 DAS were 83.8% and 34.2% lesser than the plots hand weeded twice at 20 and 40 DAS. This indicated that both ethoxysulfuron and penoxsulam *fb* HW were more effective in controlling rock bulrush than HW twice at a critical period of crop-weed competition (20 and 40 DAS). Singh *et al.* (2008) reported the ineffectiveness of HW due to weed escape and re-growth. The dry weight of rock bulrush in weedy check plots showed a steady progression from 15 to 60 DAS recording dry weights of 14.11, 35.47, 70.11 and 96.05 g/m². Higher weed dry weight indicated higher biomass production by weeds in the system.

Effect on weed control efficiency

All the herbicides were found to be equally effective in controlling rock bulrush till 30 DAS as evidenced by the higher WCE. However, at critical stages of the crop-weed competition, ethoxysulfuron *fb* HW provided higher weed control efficiencies of 99.8% and 98.1% respectively and was at par with penoxsulam 22.5 g/ha *fb* HW. The study proved the superiority of these 2 early post-emergent herbicides over HW twice for control of *Schoenoplectus juncoides*in wet-seeded rice (**Table 4**.). The study also revealed the superiority of bensulfuron methyl + pretilachlor 60 + 600 g/ha as pre-emergent spray for initial control of rock bulrush with a higher WCE. Arya and Ameena (2016) reported the superiority of pre-emergence application of bensulfuron-methyl + pretilachlor 60 + 600 g/ha in terms of WCE in semi-dry rice in comparison with HW twice.

Nutrient removal by weed

Analysis of N, P and K removal by the weed at maturity stage (60 DAS) recorded higher nutrient removal of 8.61, 3.13 and 10.95 kg NPK/ha in weedy check (**Table 5**) while, ethoxysulfuron 15 g/ha *fb* HW resulted in reduced weed dry weight and lower

Table 4. Weed control efficiencies (%) of herbicides at 15, 30, 45 and 60 DAS

Treatment	15 DAS	30 DAS	45 DAS	60 DAS
Bensulfuron-methyl + pretilachlor 60+600 g/ha at 4-7 DAS *fb* HW at 40 DAS	99.40 (10.02)	95.55 (9.82)	95.85 (9.84)	95.75 (9.84)
Penoxsulam 22.5 g/ha at 15 DAS *fb* HW at 40 DAS	24.68 (5.04)	95.31 (9.81)	99.07(10.00)	97.90 (9.94)
Ethoxysulfuron 15 g/ha at 15 DAS *fb* HW at 40 DAS	6.60 (2.68)	95.60 (9.83)	99.82(10.04)	98.07 (9.95)
Carfentrazone-ethyl 20 g/ha at 15 DAS *fb* HW at 40 DAS	16.37 (4.16)	96.08 (9.85)	97.69 (9.93)	95.74 (9.84)
Metsulfuron-methyl + chlorimuron-ethyl 4 g/ha at 20 DAS *fb* HW at 40 DAS	15.09 (3.89)	92.92 (9.69)	95.92 (9.85)	93.31 (9.71)
2,4-D sodium salt 1 kg/ha at 20 DAS *fb* HW at 40 DAS	8.38 (2.95)	94.45 (9.77)	97.34 (9.92)	96.27 (9.86)
HW at 20 and 40 DAS	15.11 (3.97)	94.66 (9.78)	98.91 (9.99)	97.08 (9.90)
Weedy check	0.00	0.00	0.00	0.00
LSD(p=0.05)	1.352	0.198	0.050	0.031

The data were subjected to square root transformation ($\sqrt{x+0.5}$) and transformed values are given in parentheses

Table 5. Nutrient removal (kg/ha) by rock bulrush in wet-seeded rice

Treatment	N	P	K
Bensulfuron-methyl + pretilachlor 60+600 g/ha at 4-7 DAS *fb* HW at 40 DAS	0.35	0.14	0.45
Penoxsulam 22.5 g/ha at 15 DAS *fb* HW at 40 DAS	0.17	0.07	0.22
Ethoxysulfuron 15 g/ha at 15 DAS *fb* HW at 40 DAS	0.16	0.07	0.20
Carfentrazone-ethyl 20 g/ha at 15 DAS *fb* HW at 40 DAS	0.34	0.14	0.44
Metsulfuron-methyl + chlorimuron-ethyl 4 g/ha at 20 DAS *fb* HW at 40 DAS	0.53	0.22	0.71
2,4-D sodium salt 1 kg/ha at 20 DAS *fb* HW at 40 DAS	0.30	0.12	0.40
HW at 20 and 40 DAS	0.24	0.10	0.31
Weedy check	8.61	3.13	10.95
LSD (p=0.05)	0.674	0.213	0.895

removal of 0.16, 0.07 and 0.20 kg NPK/ha respectively. Higher nutrient removal in the weedy check plot was in conformity with the findings of Parameswari and Srinivas (2014). Higher K removal by the weed was observed due to high K content of 1.14%. In direct-seeded rice, nutrient removal by the weeds was observed to be 34.8, 15.6 and 42.3 kg NPK/ha from un-weeded control as per the work of Singh *et al.* (2005). Higher NPK removal triggered growth and related attributes of weeds helping them to grow robust and competent.

It was concluded that in wet-seeded rice, early post-emergence application (at 15 DAS) of ethoxysulfuron 15 g/ha or penoxsulam 22.5 g/ha followed by one hand weeding at 40 DAS were effective for the management of *Schoenoplectus juncoides*.

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