



RESEARCH ARTICLE

Impact of integrated weed management strategies on weeds and rhizosphere microbial population in rice established by system rice intensification (SRI)

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ABSTRACT

A field experiment was conducted during the kharif seasons of 2022 and 2023 at the Experimental Farm, School of Agriculture, Bharath Institute of Higher Education and Research, Tamil Nadu, to assess the impact of integrated weed management treatments on weeds and rhizosphere microbial populations in rice established by system rice intensification (SRI) method. Treatments included: combinations of pre-emergence application (PE) of pyrazosulfuron-ethyl and early post-emergence application (EPoE) of bispyribac-sodium, integrated with cono weeding and hand weeding. The highest weed control efficiency (WCE) of 94.6% at 60 DAT and preservation of rhizosphere microbial populations were observed with bispyribac-sodium 30 g/ha EPoE at 15 DAT followed by (*fb*) cono weeding at 30 and 40 days after rice transplanting (DAT). In contrast, pyrazosulfuron-ethyl 25 g/ha 25 g/ha PE reduced microbial population. It is concluded that integrated weed management, comprising bispyribac-sodium 30 g/ha EPoE at 15 DAT *fb* cono weeding at 30 and 40 DAT effectively managed weeds and supported soil microbial health in rice established by SRI method.

Keywords: Actinomycetes, Bacteria, Bispyribac-sodium, Fungi, Microbial population, Transplanted rice, SRI, Weed management

INTRODUCTION

Rice (*Oryza sativa* L.) is a significant cereal crop that is extensively cultivated and serves as a primary food source in India. In India, rice is cultivated on 43.66 million hectares, yielding a total production of 118.87 million tons, with an average productivity of 2.72 t/ha. Weeds represent a significant biotic barrier that restricts yield, affecting growth and productivity through both competitive and non-competitive mechanisms (Rao *et al.* 2017; 2017a). The rice grain yield was reported to be severely reduced, due to weeds uncontrolled during the early the critical period of rice growth (Bhagavathi *et al.* 2023). Thus, weeds that appear in the initial phase of crop growth need to be managed to prevent competition during the critical period.

The use of pre-emergence herbicides is being used to control weeds emerged during early crop growth stage. However, weeds continue to emerge 10 to 20 days after pre-emergence herbicide application due to their adaptation and favourable

environment. Under such situation, early post-emergence herbicide application help managing the problem of late emerged weeds and provides improved weed control during the critical period (Dass *et al.* 2017). Herbicides are not detrimental, to rice and soil microbes when used at suggested rates and time and certain herbicides may enhance the growth and activity of the rhizosphere microflora. However, frequent use of herbicides can lead to a rise in herbicides resistant weed populations and potentially negatively impact the rhizosphere microflora community.

In system rice intensification (SRI) method of rice cultivation, weed control is achieved using cono weeder. However, lack of labour for operating cono weeders, rising labour costs and timely weeding during the initial stage of rice growth have made it necessary to employ herbicides for weed control in the SRI (Shekhawat *et al.* 2020). Studies on effect of integrating cono weeding along with herbicides and hand weeding under SRI are limited. Thus, this study was conducted with an objective to assess and identify effective integrated weed management options that includes herbicide, mechanical, and manual weeding, while studying their impact on weeds and the population of rhizosphere microflora in transplanted rice.

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MATERIALS AND METHODS

The experiment conducted during the *Kharif* seasons of 2022 and 2023 at the Experimental Farm of the School of Agriculture, Bharath Institute of Higher Education and Research (12.92080 N, 80.13060 E), Chennai, Tamil Nadu with nine treatments and three replications in a randomized block design. The tested treatments include: consisted of different combination of herbicide viz, pre-emergence application (PE) of pyrazosulfuron-ethyl 25 g/ha on 3 days of transplanting (DAT) + cono weeding at 30 and 40 DAT, pyrazosulfuron-ethyl 25 g/ha 3 DAT followed by (*fb*) hand weeding at 40 DAT, pyrazosulfuron-ethyl 25 g/ha 3 DAT *fb* cono weeding at 30 DAT and hand weeding at 40 DAT, early post-emergence application (EPOE) of bispyribac-sodium 30 g/ha 15 DAT *fb* cono weeding at 30 and 40 DAT, bispyribac sodium 30 g/ha EPOE on 15 DAT *fb* hand weeding at 40 DAT, bispyribac sodium 30 g/ha EPOE on 15 DAT *fb* cono weeding at 30 DAT and hand weeding at 40 DAT, hand weeding twice at 20 and 40 DAT, cono weeding at 10, 20, 30 and 40 DAT and unweeded control. The CO 51 crop variety for the experiment was cultivated during the *kharif* seasons of 2022 and 2023. To establish a nursery for SRI, seeds were sown at a rate of 8 kg/ha over an area of 100 m²/ha. Seedlings that were 18 days old were used for transplanting in the SRI method. A fertilizer application of 120:40:40 NPK kg/ha was utilized as the standard procedure for the experiment. According to the treatment plan, the necessary amount of herbicides was applied. Both pre-emergence and post-emergence herbicides were sprayed using a high-volume knapsack sprayer equipped with a flood jet nozzle, utilizing 500 liters of water/ha. Weed density and biomass were estimated using standard procedures. At 60 days after transplanting (DAT), the weed control efficiency (WCE) and weed index (WI) were calculated by using the formula given by Mani *et al.* (1973) and Gill and Vijayakumar (1966).

$$\text{WCE}(\%) = \frac{\text{Weed biomass in control plot} - \text{weed biomass in treated plot}}{\text{weed dry weight in control plot}} \times 100$$

$$\text{WI} = \frac{X - Y}{X} \times 100$$

Where,

X = Yield from plot with the minimum weeds (kg/ha)

Y = Yield in the respective treatment plot (kg/ha) for which the weed index to be calculated

Soil samples for microflora analysis were collected from the 0 to 15 cm topsoil at the initial stage and 20, 40, and 60 days after transplanting in all the plots across both cropping seasons. The soil samples were placed in 90 ml of deionized water at a ratio of 10 g. The mixture was stirred for 10 minutes and then allowed to settle for 5 minutes. Subsequently, 1 ml of the supernatant was diluted twofold and combined with the diluted water while keeping a constant temperature of 30°C. All samples were prepared in sets of three and used for counting microorganisms. The counts of viable microbes were assessed using the standard serial dilution and pour plating methods. The identification of bacteria and fungi was performed using soil extract agar medium (James 1958) and rose bengal agar medium (Parkinson *et al.* 1971). Kenknight's agar medium was utilized for counting actinomycetes (Wellington and Toth 1963). After creating separate microbial colonies under suitable incubation conditions, we counted the colonies and assessed the number of viable bacteria, fungi, and actinomycetes (represented as colony forming units, or cfu) per gram of dry soil weight by examining the soil dilutions (Nagamani *et al.* 2006).

RESULTS AND DISCUSSION

Effect on weeds

The dominant weed species found in the experimental field included *Echinochloa colona* and *Echinochloa crus-galli* among the grasses, *Cyperus difformis* among the sedges, and *Ammania baccifera* and *Eclipta alba* among the broad-leaved weeds in transplanted rice.

The integration bispyribac-sodium at 30 g/ha EPOE on 15 DAT *fb* cono weeding at 30 and 40 DAT recorded higher WCE at 60 DAT (94.6% and 91.6 % during 2022 and 2023, respectively) and lower WI (**Table 1**). The increased weed management efficiency during the crucial period of competition was observed with the integration of bispyribac-sodium application with cono weeding due to effective and broad-spectrum action of bispyribac-sodium against weeds which was supplemented with cono weeding and hand weeding confirming Nath *et al.* (2024). Unweeded control registered higher weed index of 51.97%. The use of herbicides for effective and broad-spectrum control of all emerged weeds during the early stages of crop growth, along with two subsequent cono weeding at 30 and 40 days after transplanting (DAT), resulted in efficient weed management and a weed-free environment throughout the crop's growth period. This reduced

Table 1. Effect of weed management treatments on weed control efficiency (%) and weed index at 60 DAT during Kharif 2022 and 2023

Treatment	Weed control efficiency (%)			Weed index
	Kharif 2022	Kharif 2023	Kharif 2022	Kharif 2023
Pyrazosulfuron-ethyl 25 g/ha PE on 3 DAT <i>fb</i> CW on 30 and 40 DAT	91.8	87.6	10.22	10.36
Pyrazosulfuron-ethyl 25 g/ha PE on 3 DAT <i>fb</i> HW at 40 DAT	91.6	87.1	10.9	11.0
Pyrazosulfuron-ethyl 25 g/ha PE on 3 DAT <i>fb</i> CW on 30 DAT and HW on 40 DAT	86.5	84.2	13.12	12.65
Bispyribac-sodium 30 g/ha EPoE on 15 DAT <i>fb</i> CW on 30 and 40 DAT	94.6	91.6	0.00	0.00
Bispyribac-sodium 30 g/ha EPoE on 15 DAT <i>fb</i> HW on 40 DAT	94.0	91.2	4.23	5.21
Bispyribac-sodium 30 g/ha EPoE on 15 DAT <i>fb</i> CW on 30 DAT <i>fb</i> HW on 40 DAT	87.2	85.4	13.68	13.63
Hand weeding twice on 20 and 40 DAT	93.7	89.1	8.69	7.32
Cono weeding on 10, 20, 30 and 40 DAT	93.9	90.0	7.02	7.55
Unweeded control	-	-	59.41	61.32
LSD (p=0.05)	17.5	16.0	10.8	11.5

PE: pre-emergence application; EPoE: early post-emergence application; DAT: days of transplanting; *fb*: followed by; CW: cono weeding; HW: hand weeding

Table 2. Effect of weed management treatments on rhizosphere bacterial population in rice at 20, 40 and 60 DAT during Kharif 2022 and 2023

Treatment	Total bacterial population (CFU x 10 ⁵ /g dry weight of soil)							
	Kharif 2022				Kharif 2023			
	Initial day	20 DAT	40 DAT	60 DAT	Initial day	20 DAT	40 DAT	60 DAT
Pyrazosulfuron-ethyl 25 g/ha PE on 3 DAT <i>fb</i> CW on 30 and 40 DAT	191	132	139	140	192	136	148	150
Pyrazosulfuron-ethyl 25 g/ha PE on 3 DAT <i>fb</i> HW at 40 DAT	192	130	135	144	191	131	139	145
Pyrazosulfuron-ethyl 25 g/ha PE on 3 DAT <i>fb</i> CW on 30 DAT and HW on 40 DAT	191	129	131	136	193	130	133	140
Bispyribac-sodium 30 g/ha EPoE on 15 DAT <i>fb</i> CW on 30 and 40 DAT	192	145	152	159	193	151	159	163
Bispyribac-sodium 30 g/ha EPoE on 15 DAT <i>fb</i> HW on 40 DAT	193	143	149	156	191	148	155	160
Bispyribac-sodium 30 g/ha EPoE on 15 DAT <i>fb</i> CW on 30 DAT <i>fb</i> HW on 40 DAT	192	133	140	142	193	145	150	156
Hand weeding twice on 20 and 40 DAT	195	175	182	185	193	173	181	184
Cono weeding on 10, 20, 30 and 40 DAT	191	177	186	188	191	175	187	190
Unweeded control	193	180	191	194	192	187	189	192
LSD (p=0.05)		14.2	14.6	14.9	-	12.6	12.1	12.5

PE: pre-emergence application; EPoE: early post-emergence application; DAT: days of transplanting; *fb*: followed by; CW: cono weeding; HW: hand weeding

Table 3. Effect of weed management treatments on rhizosphere fungal population in rice at 20, 40 and 60 DAT during Kharif 2022 and 2023

Treatment	Total fungal population (CFU x 10 ³ /g dry weight of soil)							
	Kharif 2022				Kharif 2023			
	Initial day	20 DAT	40 DAT	60 DAT	Initial day	20 DAT	40 DAT	60 DAT
Pyrazosulfuron-ethyl 25 g/ha PE on 3 DAT <i>fb</i> CW on 30 and 40 DAT	19.5	14.2	14.9	15.7	19.6	15.3	16.4	17.6
Pyrazosulfuron-ethyl 25 g/ha PE on 3 DAT <i>fb</i> HW at 40 DAT	20.4	13.9	14.6	15.3	19.5	14.0	15.1	16.6
Pyrazosulfuron-ethyl 25 g/ha PE on 3 DAT <i>fb</i> CW on 30 DAT and HW on 40 DAT	20.3	13.8	14.5	15.1	19.9	13.4	14.1	15.9
Bispyribac-sodium 30 g/ha EPoE on 15 DAT <i>fb</i> CW on 30 and 40 DAT	20.1	17.1	17.9	18.5	19.6	17.5	18.3	20.8
Bispyribac-sodium 30 g/ha EPoE on 15 DAT <i>fb</i> HW on 40 DAT	19.8	16.8	17.4	18.1	20.1	16.9	17.6	19.2
Bispyribac-sodium 30 g/ha EPoE on 15 DAT <i>fb</i> CW on 30 DAT <i>fb</i> HW on 40 DAT	19.9	16.6	17.1	17.8	19.5	16.0	17.2	18.5
Hand weeding twice on 20 and 40 DAT	20.6	18.3	18.6	19.2	20.2	19.0	20.1	22.0
Cono weeding on 10, 20, 30 and 40 DAT	20.1	18.8	19.0	19.5	19.5	19.5	20.8	22.2
Unweeded control	19.9	19.5	20.3	21.2	20.2	20.2	21.5	22.8
LSD (p=0.05)	-	1.4	1.5	1.6	-	1.9	1.6	1.8

PE: pre-emergence application; EPoE: early post-emergence application; DAT: days of transplanting; *fb*: followed by; CW: cono weeding; HW: hand weeding

crop-weed competition and minimum nutrient removal by weeds which might have increased the capacity of nutrient uptake and enhanced the source and sink sizes which in turn increased the yield. The highest net profit and BCR (Table 5) were observed with bispyribac-sodium 30 g/ha EPoE combined with cono weeding at 30 and 40 DAT. This method was

followed by the combination of bispyribac-sodium 30 g/ha EPoE *fb* cono weeding at 30 DAT *fb* hand weeding at 40 DAT. The reduction in weed competition contributed to improved crop growth and higher rice grain yields. The next best was the practice of cono weeding four times at 10, 20, 30, and 40 DAT.

Table 4. Effect of weed management treatments on rhizosphere actinomycetes population in rice at 20, 40 and 60 DAT during Kharif 2022 and 2023

Treatment	Total actinomycetes population (CFU x 10 ³ /g dry weight of soil)							
	Kharif 2022				Kharif 2023			
	Initial day	20 DAT	40 DAT	60 DAT	Initial day	20 DAT	40 DAT	60 DAT
Pyrazosulfuron-ethyl 25 g/ha PE on 3 DAT <i>fb</i> CW on 30 and 40 DAT	19.1	9.2	10.1	10.9	19.0	10.7	11.3	11.9
Pyrazosulfuron-ethyl 25 g/ha PE on 3 DAT <i>fb</i> HW at 40 DAT	18.1	8.9	9.7	10.5	19.1	9.2	10.5	10.8
Pyrazosulfuron-ethyl 25 g/ha PE on 3 DAT <i>fb</i> CW on 30 DAT and HW on 40 DAT	17.9	8.8	9.6	10.2	18.6	8.4	9.5	10.0
Bispyribac-sodium 30 g/ha EPoE on 15 DAT <i>fb</i> CW on 30 and 40 DAT	17.8	12.0	13.1	13.7	18.5	13.6	14.2	14.9
Bispyribac-sodium 30 g/ha EPoE on 15 DAT <i>fb</i> HW on 40 DAT	18.1	11.7	12.5	13.1	18.5	12.5	13.4	14.8
Bispyribac-sodium 30 g/ha EPoE on 15 DAT <i>fb</i> CW on 30 DAT <i>fb</i> HW on 40 DAT	18.5	11.5	12.1	12.8	19.1	11.9	12.8	13.4
Hand weeding twice on 20 and 40 DAT	17.9	17.9	18.5	19.1	19.4	17.5	18.0	19.1
Cono weeding on 10, 20, 30 and 40 DAT	18.5	18.2	18.7	19.4	19.2	18.0	18.3	19.4
Unweeded control	18.9	18.8	19.1	19.6	19.3	19.8	20.3	21.6
LSD (p=0.05)	-	1.2	1.4	1.5	-	1.1	1.6	1.3

PE: pre-emergence application; EPoE: early post-emergence application; DAT: days of transplanting; *fb*: followed by; CW: cono weeding; HW: hand weeding

Table 5. Effect of weed management treatments on yield and economics of rice at 20, 40 and 60 DAT during Kharif 2022 and 2023

Treatment	Kharif 2022				Kharif 2023			
	Grain yield (t/ha)	Straw yield (t/ha)	Net profit (x10 ³ Rs/ha)	BCR	Grain yield (t/ha)	Straw yield (t/ha)	Net profit (x10 ³ Rs/ha)	BCR
Pyrazosulfuron-ethyl 25 g/ha PE on 3 DAT <i>fb</i> CW on 30 and 40 DAT	4.53	581	53.72	1.98	4.27	5.63	52.20	2.04
Pyrazosulfuron-ethyl 25 g/ha PE on 3 DAT <i>fb</i> HW at 40 DAT	4.32	553	48.49	1.89	4.10	5.33	48.03	1.96
Pyrazosulfuron-ethyl 25 g/ha PE on 3 DAT <i>fb</i> CW on 30 DAT and HW on 40 DAT	4.03	501	41.20	1.75	3.92	4.96	43.33	1.86
Bispyribac-sodium 30 g/ha EPoE on 15 DAT <i>fb</i> CW on 30 and 40 DAT	5.32	682	72.54	2.33	5.18	6.51	73.08	2.46
Bispyribac-sodium 30 g/ha EPoE on 15 DAT <i>fb</i> HW on 40 DAT	5.28	671	71.24	2.30	4.98	6.50	69.09	2.38
Bispyribac-sodium 30 g/ha EPoE on 15 DAT <i>fb</i> CW on 30 DAT <i>fb</i> HW on 40 DAT	4.11	531	43.73	1.80	4.00	5.11	45.36	1.90
Hand weeding twice on 20 and 40 DAT	4.95	660	61.39	2.18	4.53	5.23	56.20	2.12
Cono weeding on 10, 20, 30 and 40 DAT	4.93	624	62.84	1.15	4.37	6.10	55.79	2.11
Unweeded control	2.98	407	17.33	1.38	2.51	3.85	11.74	1.23
LSD (p=0.05)	0.40	260	-	-	0.38	0.20	-	-

PE: pre-emergence application; EPoE: early post-emergence application; DAT: days of transplanting; *fb*: followed by; CW: cono weeding; HW: hand weeding

Rhizosphere microflora

Various weed management treatments significantly (p=0.05) affected the microbial communities during different growth stages of rice (Table 2,3,4). Unweeded control and cono weeding recorded the highest rhizosphere bacterial, fungal and actinomycetes population at 20, 40, 60 DAT in both the seasons due to none disturbance of soil without herbicide application, confirming the findings of Kundu *et al.* (2020). The improved soil aeration caused by cono weeding might have increased enzymatic activity as well as soil microbial population as observed by Pattanayak *et al.* (2022).

Among the treatments, bispyribac-sodium EPoE applied treatments recorded moderately higher rhizosphere bacterial, fungal and actinomycetes populations at 20, 40 and 60 DAT during both years. However, these microbial populations were lesser than those recorded under unweeded control.

Irrespective of herbicides, there was an increase in the population after 20 DAT. This might be due to degradation of herbicides in soil and reduced toxicity, which favored the increase in the microbial population, confirming Brochado *et al.* (2023), who observed that herbicides did not have harmful effects 30 days after the post-application.

However, the rhizosphere bacterial, fungal and actinomycetes population sharply declined in pyrazosulfuron-ethyl at 25 g/ha applied treatments when compared with the initial microflora population might be due to the toxicity of herbicides on microbes, confirming the findings of Bonnet *et al.* 2007, who also reported that herbicides have toxic effects on microorganisms before degradation. But among the different days of intervals at 20, 40 and 60 DAT, the level of microbial population gradually increased from 20 DAT as the days of pyrazosulfuron-ethyl application interval increased to 40 and 60 DAT.

It can be concluded that bispyribac-sodium 30 g/ha EPoE on 15 DAT *fb* cono weeding on 30 and 40 DAT managed weeds, during the critical period of crop-weed competition, in rice established by SRI method without any negative effects on the microbial population in the rice rhizosphere.

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