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Research Paper

Effect of herbicide and varying rates of straw mulching on weed dynamics, productivity and profitability of rice

SUBHAPRADA DASH[1], ANKITA PRIYADARSHINI[2], JAGADISH JENA[3], STUTI DEBAPRIYA BEHERA[4], TANMOY SHANKAR[5], JNANA BHARATI PALAI[6] AND BASUDEV BEHERA[7]

Faculty of Agricultural Sciences, Siksha 'O' Anusandhan, Deemed to be University, Bhubaneswar, Odisha 751 029

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ABSTRACT

In *kharif* 2022 and 2023 a field study was conducted in randomized complete block design with three replications for evaluating eleven treatments comprised of sole application of pendimethalin (750 g/ha) and bispyribac-Na (25 g/ha), rice straw mulch (RSM) (4, 6 and 8 t/ha), combination of pendimethalin along with variable rates of RSM, sequential application of pendimethalin *fb* bispyribac-Na and compared with weed free and weedy check. The study revealed that among the herbicidal and straw mulching treatments, the application of pendimethalin *fb* RSM 8 t/ha registered significantly the minimum density and biomass of total and all categories of weeds, except broad leaved weeds (BLWs) at 45 DAS. However, it was followed by the application of pendimethalin *fb* RSW 6 t/ha and pendimethalin *fb* bispyribac-Na application. The weed-free treatment registered the maximum weed control efficiency (WCE) and the minimum density and biomass of broad-leaved weeds, which was at par with pendimethalin *fb* bispyribac-Na treatment. Weed-free plot produced the maximum grain yield of 3.98 t/ha, which was at par with the application of pendimethalin *fb* straw mulching at 8t/ha (3.86 t/ha), pendimethalin *fb* bispyribac-Na (3.77 t/ha) and pendimethalin *fb* straw mulching at 6 t/ha (3.74 t/ha) treatments. Further, economic analysis revealed that the sequential application pendimethalin 750 g/ha (Pre) *fb* bispyribac-Na 25 g/ha (Post) fetch maximum net return (Rs.45,282/ha), which was followed by the integration of pendimethalin 750 g/ha *fb* RSM 6 t/ha (Rs.31,056/ha) in DSR. These treatments could manage the diverse weed flora and obtain higher grain yield and more significant profit in direct-seeded rice.

Key words: Direct-seeded rice, Integrated weed management, Mulching, Rice straw, Weed

Direct-seeded rice (DSR) has appeared as a promising substitute to transplanting. Still, one of the challenges with DSR is its lower productivity compared to transplanted rice, primarily due to the competition of weeds with the crop, which can lead to yield losses ranging from 35–90% (Chowdhury *et al*., 2021). In direct seeding of rice, it is imperative to take care of the crop from multiple flushes of diverse weed flora. The weed infestation causes a significant yield reduction during the early stage of crop growing, i.e., the critical period of crop-weed competition. Severe infestation of weeds in direct seeded rice is the main problem which causes yield loss up to 80% (Sangramsingh *et al.,* 2022). Various approaches are prevailing to manage these diverse weeds, such as preventive, physical, mechanical, cultural, and chemical approaches. Manual weeding is a traditional weed control practice, but it is a time-consuming, labour-intensive, and costlier for large-scale applications. Consequently, there has been a shift towards herbicide application as a more practical alternative for weed control in DSR. Broad-spectrum herbicides are applied either as pre- or early post-emergence application and can reduce the weed density and enhance grain yield (Dash *et al*., 2021 and Dash *et al*., 2016a). However, continuous and indiscriminate use of herbicide may lead to weed flora shift, residue retention, resistance development in weeds against the herbicides, soil health degradation and so on (Kumar *et al*., 2023). Cultural practices like application of rice straw mulch (RSM) offer another approach to suppress diverse weed flora in DSR, however, it has lower weed control efficiency (WCE). Thus, a solo weed control approach is not sustainable over a long period. Combining weed control strategies like RSM with herbicide application can provide integrated

[1]**Corresponding author's Email:** subhapradadash@soa.ac.in
[1]Associate Professor, [3,4]Assistant Professor, [7]Professor, [2]Ph.D. Scholar, Department of Agronomy, Faculty of Agricultural Sciences, Siksha 'O' Anusandhan, Deemed to be University, Bhubaneswar, Odisha 751 030; [5]Associate Professor, [6]Assistant Professor, Department of Agronomy, M.S. Swaminathan School of Agriculture, Centurion University of Technology and Management, Paralakhemundi, Odisha 761 211

weed management solutions that minimise reliance on herbicides, addressing environmental concerns associated with modern agricultural practices (Sangramsingh *et al*., 2022). Application of oxadiargyl (mention rate and time of application) *fb* RSM at 6 t/ha and oxadiargyl (mention rate and time of application) *fb* hand weeding (after how many days) treatments were noted to have the maximum grain yield after weed-free in DSR (Sangramsingh and Dash, 2021). Considering these factors, the current investigation aims to study the impact of herbicide and varying rates of RSM on weed growth, yield and profitability of *kharif*-grown DSR.

MATERIALS AND METHODS

The field investigation was conducted at the Agricultural Farm, Binjhagiri, Khurdha, SOA, Odisha, during the *kharif* 2022 and 2023. The rainfall received during the crop growing period in *kharif* 2022 and 2023 was 775.5 mm and 624.2 mm, respectively. The field was acidic in soil reaction (*p*H = 5.83). The soil was medium in available phosphorous (18.9 kg/ha), whereas it was low in organic carbon (0.39%), available nitrogen (206.0 kg/ha) and potassium (103.5 kg/ha). The experiment was replicated three times in the randomised block design with eleven treatments comprised of sole and combined application of varying rate of RSM and herbicides. The spraying of pendimethalin and bispyribac sodium was done at 1 and 25 DAS with the recommended dose of herbicides, respectively. The straw from the preceding rice crop was air-dried and applied as mulch after three days of sowing. Rice *cv* '*sahabaghidhan*' seeds of 75 kg/ha were sown with a row spacing of 20 cm. The plot size was 20 m^2. The recommended dose of nitrogen (N: 60 kg/ha), phosphorus (P_2O_5: 30 kg/ha) and potassium (K_2O: 30 kg/ha) was applied basally through urea, diammonium phosphate and muriate of potash, respectively. Before sowing, basal dose of $1/4^{th}$ N, full dose of phosphorus and potassium were given and the remaining quantity of nitrogen was top dressed in two splits i.e. ½ and $1/4^{th}$ N at 21 and 40 DAS, respectively. At 45 DAS, the observations on the density of grasses, BLWs and sedge weeds were recorded by placing a quadrate of 50 cm × 50 cm at four different spots in each plot, and all the weeds inside the quadrat were harvested from the ground level. After weed counting, to record the weed biomass, the weeds samples were sun-dried and oven-dried at 70^{o}C until constant weight was achieved. Rice grain and straw yield was obtained from the undisturbed net plot area (4.6 m × 3.6 m) and expressed in t/ha. The crop was harvested at its maturity stage on 28th September, 2022 and 20th September, 2023. The analysis of variance method as described by Gomez and Gomez (2003) was followed to analyze the experimental data statistically. The significance of different sources of variation was tested by "Error Mean Square Method" of F test at probability level 0.05. Data showing wide variation and having the value zero in weed density and biomass, were subjected to square root transformation [$\sqrt{(x + 0.5)}$] before statistical analysis to normalize their distribution.

RESULTS AND DISCUSSION

Eight weed species were found in the experimental field. *Echinochloa colona* and *Digitaria sanguinalis* among the grasses, *Melochia corchorifolia* and *Ludwigia parviflora* among the broadleaved weeds and *Cyperus iria* among the sedge were predominantly found in the experimental field. The dominance of *E. colona* and *L. parviflora* also caused significant yield reduction in rice cultivation (Dash *et al*., 2016b and Teja *et al*., 2017). All the treatments showed a significant reduction of weeds in terms of density and biomass compared to the weedy check (Table 1). Besides the weed free and sequential herbicidal application treatments, application of pendimethalin at 750 g/ha *fb* RSM 8 t/ha (T_9) registered the minimum density and biomass of grasses at 45 DAS, which was at par with the application of pendimethalin 750 g/ha *fb* RSM6 t/ha (T_8) (Table 1). Regardless of weed management treatments, RSM 9.00 t/ha resulted in considerably lower biomass of weeds than RSM 6.25 t/ha (Chakraborti *et al*., 2017). Similar effects of RSM on weed growth were also observed by Singh and Saini (2008) in Japanese mint and Singh *et al.* (2019) in wheat. They hypothesized that weed suppression under straw mulch might be attributed to one or combinations of reasons, *viz*., the effect of light transmittance, soil temperature and soil moisture; release of allelochemicals by decomposed straw; mechanical hindrance or direct suppression of the emerging weeds; reduced N-availability; or weed seed predation.

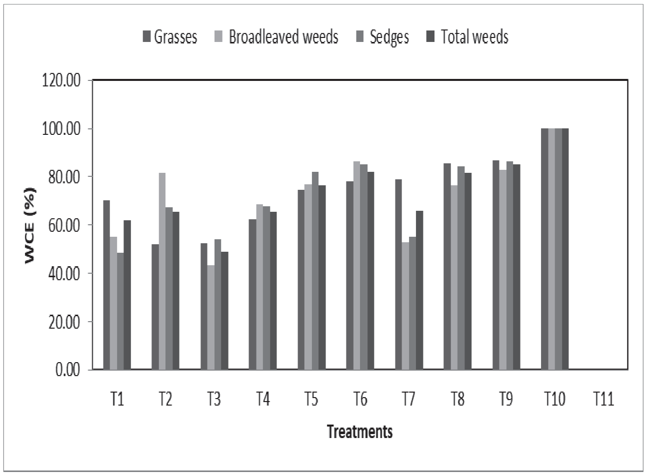
Further, sequential application of pendimethalin 750 g/ha *fb* bispyribac-Na 25 g/ha (T_6) showed significant suppression of BLWs and recorded the lowest weed biomass, which was closely followed by T_9 treatment. Similar to our findings, Nath *et al.* (2020) also recorded the highest weed control with the sequential application of pendimethalin 750 g/ha (Pre) *fb* bispyribac-Na 25 g/ha (Post) after weed-free treatment. In the case of sedge and total weeds density and biomass, were statistically at par with T_6, T_9, and T_8 treatments (Table 1).

The weed control efficiency (WCE) was calculated for all the categories of weeds, i.e. grasses, BLWs, sedge and total weeds (Figure 1). Among the herbicidal and straw mulching treatments, the application of pendimethalin 750 g/ha *fb* RSM 8 t/ha ensued in higher WCE for all the categories of weeds, except BLWs. For BLWs, sequential

Table 1. Effect of weed management treatments on density, biomass of weeds and yield of direct seeded rice (pooled data of 2 years)

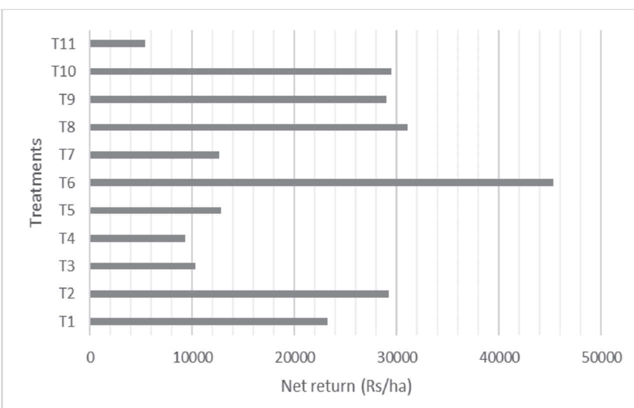
Treatment	Weed density (no./m^2) at 45 DAS				Weed biomass (g/m^2) at 45 DAS				Grain yield (t/ha)	Straw yield (t/ha)
	Grasses	BLWs	Sedges	Total Weeds	Grasses	BLWs	Sedges	Total Weeds		
T_1, Pendimethalin at 750 g/ha	5.64c (31.3)	5.35bc (28.2)	2.54bc (6.0)	8.12c (65.5)	3.74d (13.5)	4.15c (16.8)	2.08b (3.8)	5.88c (34.1)	2.62cde	2.98fgh
T_2, Bispyribac-sodium at 25g/ha	5.76c# (32.6)*	4.15de (16.8)	2.34cd (5.0)	7.41d (54.5)	4.71b (21.8)	2.70ef (6.8)	1.71c (2.4)	5.61c (31.0)	2.85bc	3.36cde
T_3, RSM at 4t/ha	6.59b (43.0)	5.74b (32.5)	2.68bc (6.7)	9.09b (82.2)	4.69b (21.5)	4.65b (21.2)	1.97bc (3.4)	6.82b (46.2)	2.41e	2.71h
T_4, RSM at 6t/ha	5.93c (34.8)	5.10c (25.5)	2.26cde (4.7)	8.08c (64.8)	4.18c (16.9)	3.48d (11.6)	1.69c (2.4)	5.61c (31.0)	2.57de	2.84gh
T_5, RSM at 8t/ha	5.07d (25.3)	4.56d (20.3)	1.86ef (3.0)	7.01d (48.7)	3.45de (11.5)	3.01e (8.6)	1.34d (1.3)	4.67d (21.3)	2.93b	3.29def
T_6, Pendimethalin *fb* bispyribac-Na	4.70de (21.6)	3.72e (13.3)	1.68f (2.3)	6.14e (37.3)	3.23e (10.0)	2.36f (5.1)	1.27d (1.1)	4.08ef (16.1)	3.77a	3.94abc
T_7, Pendimethalin *fb* RSM at 4t/ha	5.15d (26.0)	5.31bc (27.8)	2.96ab (8.3)	7.92c (62.2)	3.17e (9.5)	4.23bc (17.6)	1.95bc (3.3)	5.56c (30.5)	2.66cd	3.11efg
T_8, Pendimethalin *fb* RSM at 6t/ha	4.29ef (18.0)	4.45d (19.3)	1.95def (3.3)	6.41e (40.7)	2.66f (6.6)	3.04de (8.7)	1.29d (1.2)	4.12e (16.5)	3.74a	3.84abc
T_9, Pendimethalin *fb* RSM at 8t/ha	4.22f (17.4)	3.87e (14.7)	1.84ef (3.0)	5.95e (35.0)	2.55f (6.0)	2.59ef (6.3)	1.22d (1.0)	3.71f (13.3)	3.86a	4.03ab
T_{10}, Weed-free	0.71g (0.0)	0.71f (0.0)	0.71g (0.0)	0.71f (0.0)	0.71g (0.0)	0.71g (0.0)	0.71e (0.0)	0.71g (0.0)	3.98a	4.19a
T_{11}, Weedy check	7.77a (60.0)	6.60a (43.2)	3.38a (11.0)	10.70a (114.2)	6.77a (45.4)	6.14a (37.3)	2.81a (7.4)	9.51a (90.1)	1.69f	1.66i
SEm±	0.16	0.16	0.15	0.17	0.11	0.16	0.10	0.14	0.09	0.12
CD (P=0.05)	0.48	0.47	0.43	0.49	0.33	0.47	0.30	0.41	0.25	0.35

RSM, Rice Straw Mulch. *Original value presented in parenthesis. Data is subjected to square root transformation (x+0.5) before statistical analysis, #Same letters indicate non-significant differences among the treatment



T_1, Pendimethalin at 750 g/ha; T_2, Bispyribac-sodium at 25 g/ha; T_3, Straw mulching at 4 t/ha; T_4, Straw mulching at 6t/ha; T_5, Straw mulching at 8t/ha; T_6, T_1 *fb* T_2; T_7, T_1 *fb* T_3, T_8, T_1 *fb* T_4, T_9, T_1 *fb* T_5, T_{10}, Weed free; T_{11}, Weedy check

Fig. 1. Weed Control Efficiency of different weed management practices for grasses, broadleaf weeds, sedges and total weeds in direct-seeded rice at 45 DAS (Pooled data for 2 years)



T_1, Pendimethalin at 750 g/ha; T_2, Bispyribac-sodium at 25 g/ha; T_3, Straw mulching at 4 t/ha, T_4, Straw mulching at 6 t/ha; T_5, Straw mulching at 8 t/ha; T_6, T_1 *fb* T_2, T_7, T_1 *fb* T_3, T_8, T_1 *fb* T_4, T_9, T_1 *fb* T_5, T_{10}, Weed free, T_{11}, Weedy check

Fig. 2. The net return of direct-seeded rice under different weed management practices (Pooled data for 2 years)

application of pendimethalin 750 g/ha *fb* bispyribac-Na 25 g/ha recorded the higher WCE, next only to the weed-free treatment. The higher WCE with these treatments might be attributed to the lower weed biomass accumulation in these treatments. The WCE for grass, BLWs, sedges and total weeds was the highest with three-hand weeding from 15 to 45 DAS at 15-day intervals, and this treatment was followed by pendimethalin 1000 g/ha at 3 DAS *fb* bispyribac-Na 25 g/ha at 20 DAS (Saravanane, 2020).

The grain and straw yield of DSR varied significantly among the treatments (Table 1). Weed-free check produced the maximum grain yield (3.98 t/ha) which was closely followed by the application of pendimethalin 750 g/ha *fb* RSM 8 t/ha (3.86 t/ha), pendimethalin 750 g/ha *fb* bispyribac-Na 25 g/ha (3.77 t/ha) and pendimethalin at 750 g/ha *fb* RSM 6 t/ha (3.74 t/ha) treatments (Table 1). This might be due to the reduced weed infestation in these treatments throughout the growth stages, thus enabling the crop for optimum utilisation of resources that ultimately lead to higher grain and straw yield. Weedy check registered the minimum grain and straw yield among the treatments. Similarly, to our experimental findings Sangramsingh and Dash (2021) also noticed that integrated application of pendimethalin *fb* RSM 6 t/ha effectively reduced the weed density and biomass, which led to an increase in the grain yield in DSR. Further, economic analysis of treatment revealed that sequential application of pendimethalin 750 g/ha *fb* bispyribac-Na 25 g/ha recorded the maximum net returns (Rs. 45,282/ha), which was followed by the integrated application of pendimethalin 750 g/ha *fb* RSM 6 t/ha (Rs 31,056/ha) in DSR (Figure 2). This result is in accord with a recent study indicating that integrated application of oxadiargyl 70 g/ha at 1 DAS *fb* RSM 6 t/ha at 3 DAS resulted in maximum net returns (Rs. 17,530/ha) of DSR (Sangramsingh *et al*., 2022).

From the result of the field experiment, it was concluded that the integrated application of pendimethalin 750 g/ha *fb* rice straw mulch 6 t/ha and sequential application of pendimethalin 750 g/ha *fb* bispyribac-Na at 25 g/ha may be recommended for managing diverse weed flora, obtaining enhanced grain yield and more significant profit in DSR during *kharif* season.

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