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Research Communication

Effect of integrated application of herbicides and straw mulch on productivity and profitability of rainfed upland rice (*Oryza sativa*)

P.K. SANGRAMSINGH[1], SUBHAPRADA DASH[2], MD. R. CHOWDHURY[3], S.S. NANDA[4], K. SAR[5], BASUDEV BEHERA[6] AND J.M.L. GULATI[7]

Agricultural Research Station, Faculty of Agricultural Sciences, Siksha 'O' Anusandhan, (Deemed-to-be University), Binjhagiri, Chhatabar, Odisha 752 054

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ABSTRACT

A field study was carried out during rainy (*kharif*) season of 2019 at Agricultural Research Station, Faculty of Agricultural Sciences, Siksha 'O' Anusandhan, Bhubaneswar, Binjhagiri, Chhatabar, Odisha, to evaluate the effect of herbicide and varying rates of straw mulching on weed growth, productivity and profitability of direct-seeded rice (*Oryza sativa* L.). Twelve treatments were replicated thrice in a randomized complete-block design. The predominant weeds in the experimental area were: annual blue grass (*Poa annua* L.), large crab grass [*Digitaria sanguinalis* (L.) Scop.], jungle rice [*Echinochloa colona* (L.) Link.], rice flat sedge (*Cyperus iria* L.), perennial water primrose (*Ludwigia* perennis L.), chocolate weed (*Melochia corchorifolia* L.), and alligator weed [*Alternanthera philoxeroides* (Mart.) Griseb.]. Application of oxadiargyl followed by (*fb*) rice straw mulch at 6 t/ha and oxadiargyl *fb* hand-weeding registered lower weed density (25.0/m^2), biomass (13.4 g/m^2), and higher values of growth parameters (plant height, 65.1cm; tiller density, 236/m^2; dry-matter accumulation, 318.2 g/m^2) of rice. The maximum grain yield of 3.05 t/ha was recorded under the weed-free treatment, followed by oxadiargyl *fb* rice straw mulch at 6 t/ha (2.99 t/ha) and oxadiargyl *fb* hand-weeding (2.90 t/ha). Application of oxadiargyl *fb* rice straw mulch at 6 t/ha resulted in a higher net returns of ₹17,530/ha and benefit : cost ratio of 0.52.

Key words: Direct-seeded rice, Mulching, Oxadiargyl, Pendimethalin, Weeds

In recent years, direct-seeded rice (DSR) has been introduced as an alternative to transplanted rice to minimize methane emission, apart from saving water, labour and energy. Properly managed DSR crop yields comparable with transplanted rice (Pathak *et al*., 2013). However, the lower productivity is common in DSR, mainly due to weed infestation resulting in yield loss of 50–91% (Mathew *et al*., 2013). Though the manual weeding is an effective and safe practice to the crop, it requires huge physical energy, which makes it cost intensive and hard to apply in larger areas. Alternatively, the herbicide application in place of manual weed control shows promise for higher weed-control efficiency with least cost. But weed management by herbicides alone is not advisable for the sustainability point of view. Continuous application of a particular herbicide led to herbicide resistance. Cultural practices such as use of rice straw mulch to suppress weed growth can be considered as a viable option. Devasinghe *et al*. (2011) reported that, rice straw mulch was effective in controlling weeds of rice. Integration of herbicides with rice straw mulch seems to be a feasible option for weed management in rice which helps in minimizing the adverse impact of agrochemicals on environment. Reducing chemical load in the environment is a major concern of the current agricultural scenario. Keeping all these aforesaid issues in view, the present experiment was conducted with an objective to study the effect of herbicide and varying rates of straw mulch on weed growth, productivity and profitability of direct-seeded rice.

The field experiment was conducted at the Agricultural Research Station, Faculty of Agricultural Sciences, SOA, Binjhagiri, Chhatabar, Odisha during the rainy (*kharif*) season of 2019. The farm is situated at 20° 15′ N, 85° 40′ E, 58 m above the mean sea level in East and South Eastern Coastal Plain Agro-climatic Zone of Odisha, India. The experimental plot was a typical upland having a well-drained soil and fairly uniform topography. The soil was

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[2]Corresponding author's Email: subhapradadash@soa.ac.in

[1]M.Sc. (Agriculture) Scholar, [5]Assistant Professor, [2,3]Associate Professor, [4,6,7]Professor, Department of Agronomy, Faculty of Agricultural Sciences, SOA, Bhubaneshwar, Odisha 751 029

loamy in texture and acidic (*p*H 5.82). The soil was low in both organic carbon (0.48%), and available nitrogen (206.8 kg/ha) but medium in both available phosphorus (20.4 kg/ha) and potassium (131.2 kg/ha).

The experiment comprising 12 treatments (Table 1) was laid out in a randomized complete-block design, with 3 replications. Herbicide spraying was done by using knapsack sprayer with flat-fan nozzle as per treatment specifications. The air-dried straw of rice grown in the previous year was used as mulch. The rice straw was spread in the inter-row space of rice 3 days after sowing (DAS). Rice cv 'Mandakini' was sown at a row-to-row spacing of 20 cm at a depth of 3 cm in north-south direction, using the seed rate of 75 kg/ha. The crop was fertilized with 60, 30 and 30 kg N, P_2O_5 and K_2O/ha through urea, diammonium phosphate, and muriate of potash. The entire phosphorus and potassium along with 25% N were applied basal at the time of sowing. The remaining N was applied in 2 splits, viz. 50% at tillering stage (21 days after sowing) and the remaining 25% N was applied at the panicle-initiation stage (45 days after sowing). Crop received a total of 1,189.3 mm rainfall during its growing period with 307.3, 291.2, 354.2 and 236.6 mm falling in the month of July, August, September and October respectively. Rice was harvested manually with the sickles at a height of 5–7 cm from the ground surface and threshed manually.

Observations on the growth parameters were recorded at 60 days after sowing (DAS) by following standard procedure. The density and biomass of weed were recorded at 60 DAS from 2 randomly selected quadrates, each of size 50 cm × 50 cm, from sampling area of each plot. For recording their biomass, weed samples were cut close to the ground level, sun-dried and later oven-dried at 65 ± 5°C until the constant weight was attained. Grain yield was taken from the undisturbed net plot area (5 m × 4 m) in the centre of each plot and expressed in t/ha. Observations exhibiting wide variation and having the value zero (weed density and biomass) were subjected to $\sqrt{(x + 0.5)}$ transformation to make the analysis of variance valid.

The experimental field was infested with 7 predominant weed species comprising grasses, viz. annual blue grass (*Poa annua* L.), large crab grass [*Digitaria sanguinalis* (L.) Scop.], jungle rice [*Echinochloa colona* (L.) Link.]; sedges, vig. rice flat sedge (*Cyperus iria* L.); broad-leaf weeds, viz. perennial water primrose (*Ludwigia perennis* L.), chocolate weed (*Melochia corchorifolia* L.) and alligator weed [*Alternanthera philoxeroides* (Mart.) Griseb.]. Dash *et al*. (2016) also reported the dominance of *Echinochloa colona, C. iria* and *A. philoxeroides* in rice. Among weed-management practices, oxadiargyl *fb* rice straw mulch at 6 t/ha and oxadiargyl *fb* hand-weeding, significantly reduced the weed density (25.0 and 29.1/m^2 respectively) and biomass (13.4 and 13.7 g/m^2 respectively) of weeds at 60 DAS (Table 1). The reduction of weed density and

Table 1. Effect of weed management practices on weed and crop growth at 60 days after sowing

Treatment	Weed density (No./m^2)	Weed biomass (g/m^2)	Weed control efficiency (%)	Plant height (cm)	Tiller density (No./m^2)	Dry-matter accumulation (g/m^2)
T_1 Pendimethalin at 750 g/ha at 1 DAS	8.5** (71.2*)	6.9 (47.6)	59.24	46.3	185	270.3
T_2, Oxadiargyl at 70 g/ha at 1 DAS	7.8 (59.7)	6.2 (38.7)	66.90	50.1	190	273.0
T_3, Rice straw mulch at 4 t/ha at 3 DAS	8.6 (74.3)	7.4 (54.3)	53.49	44.8	175	269.8
T_4, Rice straw mulch at 6 t/ha at 3 DAS	7.8 (59.7)	6.2 (38.1)	67.39	50.4	197	277.7
T_5, Pendimethalin at 750 g/ha at 1 DAS *fb* rice straw mulch at 4 t/ha at 3 DAS	7.7 (59.3)	6.3 (39.5)	66.18	53.6	199	285.0
T_6, Pendimethalin at 750 g/ha at 1 DAS *fb* rice straw mulch at 6 t/ha at 3 DAS	6.7 (43.9)	4.9 (23.6)	79.76	59.5	212	297.8
T_7, Oxadiargyl at 70 g/ha at 1 DAS *fb* rice straw mulch at 4 t/ha at 3 DAS	6.4 (40.4)	4.7 (21.6)	81.52	60.0	217	302.0
T_8, Oxadiargyl at 70 g/ha at 1 DAS *fb* rice straw mulch at 6 t/ha at 3 DAS	5.1 (25.0)	3.7 (13.4)	88.49	65.1	236	318.2
T_9, Pendimethalin at 750 g/ha at 1 DAS *fb* 1 HW at 35 DAS	6.8 (45.8)	5.1 (25.3)	78.33	57.2	202	292.4
T_{10}, Oxadiargyl at 70 g/ha at 1 DAS *fb* 1 HW at 35 DAS	5.4 (29.1)	3.8 (13.7)	88.25	64.2	229	310.3
T_{11}, Weed-free	0.7 (0.0)	0.7 (0.0)	100.00	69.4	248	322.4
T_{12}, Weedy check	10.1 (100.5)	10.8 (116.8)	0.00	38.6	92	210.7
SEm±	0.14	0.18	-	1.91	7.15	4.34
CD (P=0.05)	0.40	0.54	-	5.61	20.98	12.72

DAS, days after sowing; HW, hand-weeding; fb, followed by

*Values in parentheses are original; **Data were square root transformed

biomass could be due to the effective control of weeds at the initial stage of crop growth because of integrating herbicide application with mulching or hand weeding. The straw mulching physically obstructed the emergence and growth of the weed species. Pasha *et al*. (2013) reported the efficacy of pre-emergence application of pendimethalin at 1 kg/ha at 1 DAS + 1 hand-weeding in reducing the weed growth in rice at Nalgonda district of Andhra Pradesh. The integration of oxadiargyl with rice straw mulch at 6 t/ha and oxadiargyl with hand-weeding proved equally effective in managing weeds at 60 DAS in the rainy season. Among the herbicidal treatments, oxadiargyl was found superior to pendimethalin in reducing weed density and biomass. Oxadiargyl, a proto porphyrinogen oxidase (PPO)-inhibitor herbicide, is very effective against diverse weed flora of rice.The integration of appropriate herbicide with straw retention or hand-weeding could be a viable weed management option to reduce the weed infestation (Maity and Mukherjee, 2008). Among the treatments, application of oxadiargyl *fb* rice straw mulch at 6 t/ha registered the maximum weed-control efficiency (WCE) of 88.49% and oxadiargyl *fb* hand-weeding with WCE of 88.25%. However, oxadiargyl *fb* rice straw mulch at 4 t/ha with WCE of 81.52% at 60 DAS can be an alternative to above treatment where the farmer has a limited rice straw to apply as mulch (Table 1).

Among the weed-management practices, the highest plant height, number of tillers/m^2 and dry-matter accumulation (DMA) were recorded under weed-free treatment, which was statistically at par with the application of oxadiargyl *fb* rice straw mulch at 6 t/ha and oxadiargyl *fb* hand-weeding (Table 1). Among the sole herbicidal treatments, application of oxadiargyl recorded significantly taller plants, more number of tillers and higher DMA than application of pendimethalin. Due to presence of higher lignin and silica, rice straw mulch showed resistance in decomposition, stayed for a longer period in the field and reduced the weed infestation which ultimately contributed to enhanced grain yield of the crop (Devasinghe *et al*., 2011)

The maximum productivity of grain (3.05 t/ha) and straw (3.90 t/ha) was recorded under the weed-free treatment but oxadiargyl *fb* rice straw mulch at 6 t/ha (2.99 t grain/ha and 3.78 t straw/ha) and oxadiargyl *fb* rice hand-weeding (2.90 t grain/ha and 3.73 t straw/ha) resulted in a comparable yield (Table 2). Compared with weedy check, the yield was higher, i.e. 80.35–81.32% for grain and 73.87–74.99% for straw yield, under weed-free treatment, oxadiargyl *fb* rice straw mulch at 6 t/ha and oxadiargyl *fb* rice hand-weeding, respectively. The grain yield was negatively correlated with weed biomass and density. Among the integrated weed management (IWM) practices, the minimum weed index (WI) was recorded for oxadiargyl *fb* rice straw mulch at 6 t/ha (1.69%), followed by oxadiargyl

Table 2. Effect of weed management practices on yield, weed index and economics of rice

Treatment	Grain yield (t/ha)	Straw yield (t/ha)	Weed index (%)	Cost of cultivation (₹/ha)	Gross returns (₹/ha)	Net returns (₹/ha)	Benefit : cost ratio
T_1 Pendimethalin at 750 g/ha at 1 DAS	2.03	2.64	33.43	26,600	34,920	8,320	0.31
T_2, Oxadiargyl at 70 g/ha at 1 DAS	2.13	2.85	29.98	25,960	36,790	10,830	0.42
T_3, Rice straw mulch at 4 t/ha at 3 DAS	1.94	2.56	36.44	31,160	33,380	2,210	0.07
T_4, Rice straw mulch at 6 t/ha at 3 DAS	2.50	3.22	17.97	33,160	43,010	9,850	0.30
T_5, Pendimethalin at 750 g/ha at 1 DAS *fb* rice straw mulch at 4 t/ha at 3 DAS	2.55	3.31	16.26	32,600	43,930	11,320	0.35
T_6, Pendimethalin at 750 g/ha at 1 DAS *fb* rice straw mulch at 6 t/ha at 3 DAS	2.75	3.52	9.62	34,600	47,370	12,760	0.37
T_7, Oxadiargyl at 70 g/ha at 1 DAS *fb* rice straw mulch at 4 t/ha at 3 DAS	2.80	3.58	8.12	31,960	48,150	16,190	0.51
T_8, Oxadiargyl at 70 g/ha at 1 DAS *fb* rice straw mulch at 6 t/ha at 3 DAS	2.99	3.78	1.69	33,960	51,490	17,530	0.52
T_9, Pendimethalin at 750 g/ha at 1 DAS *fb* 1 HW at 35 DAS	2.73	3.49	10.38	35,350	46,970	11,620	0.33
T_{10}, Oxadiargyl at 70 g/ha at 1 DAS *fb* 1 HW at 35 DAS	2.90	3.73	4.93	34,710	49,840	15,130	0.44
T_{11}, Weed-free	3.05	3.90	0.00	46,410	52,410	6,000	0.13
T_{12}, Weedy check	0.57	0.97	81.32	25,160	9,976	-15,184	-0.60
SEm±	0.053	0.058	-	-	867.8	-	-
CD (P=0.05)	0.156	0.171	-	-	2,545.3	-	-

DAS, days after sowing; HW, hand-weeding; fb, followed by

*Values in parentheses are original; **Data were square root transformed

fb rice hand-weeding (4.93%) and oxadiargyl *fb* rice straw mulch at 4 t/ha (8.12%). These findings corroborated the results of Das *et al*. (2017), who reported that the higher weed-control efficiency and weed index was observed from the mulched plots of varying thickness than bare soil.

The pendimethalin *fb* hand-weeding involved the highest cost of cultivation, followed by oxadiargyl *fb* hand-weeding and pendimethalin *fb* rice straw mulch at 6 t/ha. The highest cost of cultivation was incurred under weed-free treatment (Table 2). However, weed-free treatment fetched the highest gross returns (52,050/ha), which was at par with oxadiargyl *fb* rice straw mulch at 6 t/ha (51,490/ha) (Table 2). Among the weed-management treatments, oxadiargyl *fb* rice straw mulch at 6 t/ha resulted in the highest net returns (17,530/ha) and benefit : cost (B:C) ratio (0.52) during the rainy season (Table 2). In this treatment, the pre-emergence application of oxadiargyl kept the initial flush of weeds under control, the later flush of weeds was taken care of by the mulching at 6 t/ha. This IWM practice efficiently reduced the weed flora and maximized the growth and yield of rice and, in turn, increased the net returns. Application of pendimethalin at 1 kg/ha followed by 1 hand-weeding effectively reduced weeds and proved effective in increasing the grain yield of direct-seeded rice resulting in higher net returns (Naresh *et al*., 2011). Chaudhari *et al*. (2019) observed that, rice straw mulch 5.0 t/ha applied after planting of garlic in conjunction with either application of oxyfluorfen *fb* hand-weeding at 60 days after planting or tank-mix application of pendimethalin + oxyfluorfen recorded the highest net returns and B:C ratio. Kashid *et al.* (2015) reported that, sequential application of herbicides resulted in a higher monetary benefit compared to herbicide + hand-weeding in direct-seeded rice. However, Gaire *et al*. (2013) recorded the highest net profit obtained from the treatment with *Eupatorium* mulch.

Thus, application of oxadiargyl as pre-emergence herbicide + rice straw mulch at 6 t/ha at 3 days after sowing (DAS) proved effective in managing broad spectrum weed flora, to obtain higher yield and profitability of rainfed upland rice during the rainy season.

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