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RESEARCH NOTE

Efficacy of pre-emergence herbicides in managing weedy rice in wet-seeded rice

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ABSTRACT

An experiment was conducted during 2023-2024 in a farmer's field with a history of severe infestation of weedy rice located in Thrissur district, Kerala. The objective of the study was to identify effective pre-emergence herbicides for managing weedy rice and improving rice yield in wet-seeded rice. Twelve treatments were included, *viz.* oxyfluorfen 0.15 kg/ha just prior to sowing (0 DBS); oxyfluorfen 0.15 kg/ha at 10 days after seeding (DAS); butachlor at two doses 1.25 kg/ha and 0.625 kg/ha 7 DAS; pendimethalin 1.5 kg/ha 7 DAS; pretilachlor 0.75 kg/ha 7 DAS; pyrazosulfuron-ethyl 0.03 kg/ha 7 DAS; pretilachlor 30% + pyrazosulfuron-ethyl 0.75% (pretilachlor + pyrazosulfuron-ethyl) 0.62 kg/ha 7 DAS; pendimethalin 24% + penoxsulam 1% (pendimethalin + penoxsulam) 0.625 kg/ha 7 DAS; butachlor 38.8% + penoxsulam 0.97% (butachlor + penoxsulam) 0.82 kg/ha 7 DAS; unweeded control and weed-free check. Spraying oxyfluorfen 0.15 kg/ha just prior to sowing of pre-germinated rice seeds resulted in the highest weedy rice control efficiency (73%) at 30 DAS with grain yield reduction of only 8% compared to the 69% in unweeded control. The next best effective herbicides were oxyfluorfen 0.15 kg/ha 10 DAS and butachlor + penoxsulam 0.82 kg/ha 7 DAS, which registered 12 and 17% rice yield reduction, respectively. Phytotoxicity was observed with oxyfluorfen and butachlor, but the rice recovered within two weeks.

Keywords: Butachlor + penoxsulam, Oxyfluorfen, Pre-seeding herbicide application, Red rice, Weed management

Direct-seeding has become the primary method for rice crop establishment in many Asian countries due to rising production costs, labour shortages, increasing wage rates, and limited water resources (Rao *et al*. 2007 and 2017). However, the proliferation of weeds, particularly weedy rice (*Oryza sativa* f. *spontanea*), presents a significant challenge in direct-seeded rice (DSR) systems (Chauhan and Johnson 2010; Abraham and Jose 2015). Weedy rice is widely distributed across commercial rice-growing regions in Asia, Africa, and Latin America, especially where direct-seeding practices are common. It has several competitive advantages, such as enhanced seed dormancy, seed shattering, and vigorous proliferation, leading to substantial yield loss, often ranging from 15% to 100%. The close anatomical and physiological similarities between weedy rice and cultivated rice make selective herbicide application difficult, necessitating alternative control strategies, such as modifying herbicide application timings and techniques.

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To explore effective management strategies, a study was conducted in Thrissur district, Kerala, India, during the 2023-2024 season. The aim of the experiment was to evaluate the efficacy of different pre-emergence herbicides in controlling weedy rice in wet-seeded rice (WSR) and to identify the most effective herbicide treatments for managing weedy rice and improving wet-seeded rice yield. The selected field, with a history of severe weedy rice infestation, had sandy clay loam soil and a pH of 5.93. The experiment was laid out in randomised block design (RBD), replicated thrice, with a plot size of 5 x 4m. There were twelve treatments *viz*. unweeded control (UWC), weed-free check (hand weeding), oxyfluorfen 23.5% EC (oxyfluorfen) 0.15 kg/ha at 0 days before to sowing (0 DBS), oxyfluorfen 0.15 kg/ha at 10 days after seeding (DAS); butachlor 50% EW (butachlor)1.25 kg/ha 7 DAS; butachlor 0.625 kg/ha 7 DAS; pendimethalin 30% EC (pendimethalin)1.5 kg/ha, pretilachlor 37% EW (pretilachlor) 0.75 kg/ha 7 DAS; pyrazosulfuron-ethyl 10% WP (pyrazosulfuron-ethyl) 0.03 kg/ha 7 DAS; pretilachlor 30% + pyrazosulfuron-ethyl 0.75% WG (pretilachlor + pyrazosulfuron-ethyl) 0.62 kg/ha 7 DAS; pendimethalin 24% + penoxsulam 1% SE (pendimethalin + penoxsulam) 0.625 kg/ha 7 DAS

and butachlor 38.8% + penoxsulam 0.97% SE (butachlor + penoxsulam) 0.82 kg/ha 7 DAS. All the herbicides other than oxyfluorfen were applied on 7 DAS. The treatment with oxyfluorfen on the day of sowing was applied on puddled wet soil, and the pre-germinated rice seeds were sown immediately after spraying. Water was let into the herbicide-applied plot three days after spraying. In the weed-free check, initial hand weeding was done at 15 DAS, and periodic weeding was undertaken to keep the plot weed-free.

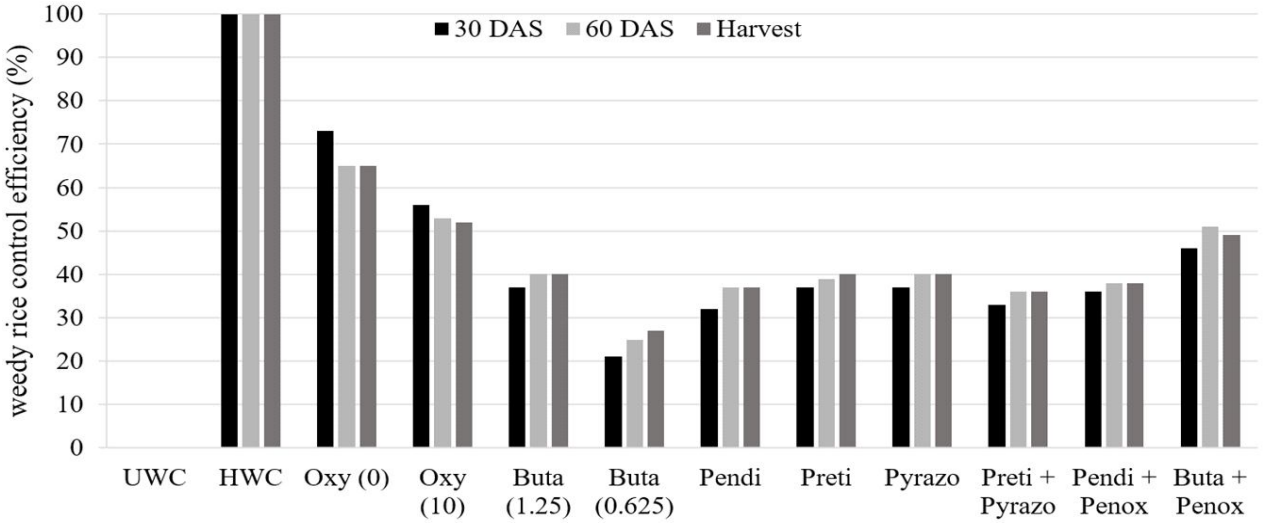
The phytotoxicity of herbicides was noted at 3, 7 and 14 days after herbicide application, using a phytotoxicity scoring scale from 0 to 5 as given by Thomas and Abraham (2007). Observation on plant height, number of tillers/m^2, grain and straw yield (kg/ha), were recorded. The data was analysed using the statistical package "GRAPES" (General R-based Analysis Platform Empowered by Statistics) developed by Gopinath *et al.* (2021). Data on parameters which showed wide variation were subjected to square root transformation [$\sqrt{x+0.5}$] to make the analysis of variance valid. Multiple comparisons among treatment means, where the F test was significant (at 5% level) were done with Tukey's HSD test (Honestly Significant Difference).

Effect on weedy rice and other weeds

The major weed flora of the experimental field was weedy rice (*Oryza sativa* f. *spontanea*). Other weeds included *Echinochloa* sp., *Fimbristylis miliacea, Ludwigia* sp., *Lindernia* sp. and *Sagittaria* sp.

Herbicide application had a significant effect on the density and biomass of weedy rice at 30 and 60 DAS and at harvest (**Table 1**). The hand-weeded plot was kept weed-free, and hence, no weedy rice was present in the field at all stages of observation. The weedy rice biotype found in the experimental plot had the same height as that of the cultivated variety even at heading stage. The grains were straw coloured and with awns ranging from 1.1 to 3.2 cm in length. The number of tillers per plant was also lower (2-3 tillers/plant) compared to typical weedy rice biotypes. Ngyuyen *et al.* (2023) documented that certain weedy rice lines display significant morphological similarities with cultivated rice, encompassing analogous growth periods, heights, husk pigmentation, and seed morphology.

Among the herbicides used, oxyfluorfen 0 DBS (on the same day of sowing) registered the lowest weedy rice density and biomass. It was statistically superior to all other herbicides due to the action of oxyfluorfen in preventing the germination of weedy rice from soil seed bank. Similar observations on the weedy rice control potential of oxyfluorfen was reported earlier by Hassan and Rao (1994) and Abraham and Jose (2015). The next best treatments were oxyfluorfen at 10 DAS and premix of butachlor + penoxsulam, respectively. The weedy rice density ranged from 17 no/m^2 with oxyfluorfen 0 DBS to 60 no/m^2 in unweeded control at 30 DAS. The weedy rice density showed a slight increase at rice harvest stage and ranged from 26 to 72 no/m^2. The weedy rice density and biomass were highest in the unweeded control at all growth stages.



UWC - unweeded control, HWC-weed-free check, Oxy (0) – oxyfluorfen at 0 DBS; Oxy (10) - oxyfluorfen at 10 DAS, Buta (1.25) - butachlor at 1.25 kg/ha; Buta (0.625) - butachlor (0.625 kg/ha), + penoxsulam; Pendi - pendimethalin, Preti - pretilachlor, Pyrazo – pyrazosulfuron-ethyl, Preti + Pyrazo - pretilachlor + pyrazosulfuron-ethyl, Pendi + Penox – pendimethalin + penoxsulam, and Buta + Penox - butachlor + penoxsulam; *DAS = days after seeding; DBS = days before seeding

Figure 1. Effect of weed management treatments on weedy rice control efficiency

Table 1. Effect of weed management treatments on weedy rice density and biomass

Treatment	Weedy rice density (no./m^2)			Weedy rice biomass (g/m^2)		
	30 DAS	60 DAS	Harvest	30 DAS	60 DAS	Harvest
Unweeded control	7.80^{a} (60.33)	8.21^{a} (67.00)	8.49^{a} (71.67)	11.50^{a} (131.71)	13.89^{a} (192.62)	16.64^{a} (276.6)
Weed free check (hand weeded)	0.71^{g} (0.00)	0.71^{f} (0.00)	0.71^{f} (0.00)	0.71^{g} (0.00)	0.71^{f} (0.00)	0.71^{f} (0.00)
Oxyfluorfen 0.15 kg/ha 0 DBS	4.22^{f} (17.33)	4.88^{e} (23.33)	5.11^{e} (25.67)	6.06^{f} (36.22)	8.18^{e} (66.46)	9.81^{e} (95.74)
Oxyfluorfen 0.15 kg/ha 10 DAS	5.30^{e} (27.67)	5.70^{d} (32.00)	5.99^{d} (35.33)	7.67^{e} (58.48)	9.53^{d} (90.33)	11.59^{d} (133.73)
Butachlor 1.25 kg/ha 7 DAS	6.23^{cd} (38.33)	6.42^{c} (40.67)	6.64^{bc} (43.67)	9.15^{cd} (83.19)	10.77^{c} (115.63)	12.94^{c} (167.07)
Butachlor 0.625 kg/ha 7 DAS	6.82^{b} (46.00)	7.08^{b} (49.67)	6.87^{b} (46.67)	10.22^{b} (103.91)	12.00^{b} (143.51)	14.27^{c} (203.02)
Pendimethalin 1.5 kg/ha 7DAS	6.49^{bc} (41.67)	6.55^{c} (42.33)	6.77^{b} (45.33)	9.46^{c} (89.01)	11.01^{c} (120.65)	13.25^{c} (174.98)
Pretilachlor 0.75 kg/ha 7DAS	6.23^{cd} (38.33)	6.44^{c} (41.00)	6.62^{bc} (43.33)	9.11^{cd} (82.49)	10.82^{c} (116.57)	12.91^{c} (166.14)
Pyrazosulfuron-ethyl 0.03 kg/ha 7 DAS	6.20^{cd} (38.00)	6.42^{c} (40.67)	6.62^{bc} (43.33)	9.11^{cd} (82.5)	10.78^{c} (115.76)	12.88^{c} (165.54)
Pretilachlor + pyrazosulfuron-ethyl 0.62 kg/ha 7 DAS	6.46^{bc} (41.33)	6.57^{c} (42.67)	6.84^{b} (46.33)	9.41^{c} (88.13)	10.97^{c} (123.93)	13.34^{c} (177.65)
Pendimethalin + penoxsulam 0.625 kg/ha 7DAS	6.28^{cd} (39.00)	6.54^{c} (42.33)	6.74^{b} (45.00)	9.18^{c} (83.86)	10.97^{c} (119.99)	13.13^{c} (171.91)
Butachlor + penoxsulam 0.82 kg/ha 7 DAS	5.90^{d} (34.33)	5.90^{d} (34.33)	6.29^{cd} (39.00)	8.49^{d} (71.62)	9.71^{d} (93.84)	11.84^{d} (139.77)

$\sqrt{x+0.5}$ transformed values, original values in parenthesis. In a column, means followed by common letters do not differ significantly at 5% level in Tukey's Test.; DAS = days after seeding; DBS = days before seeding

Table 2. Phytotoxicity of herbicides on rice

Treatment	Days after spraying		
	3	7	14
Oxyfluorfen 0.15 kg/ha 0 DBS	2	2	0
Oxyfluorfen 0.15 kg/ha 10 DAS	3	3	0
Butachlor 1.25 kg/ha 7 DAS	2	2	0
Butachlor 0.625 kg/ha 7 DAS	0	0	0
Pendimethalin 1.5 kg/ha 7 DAS	1	0	0
Pretilachlor 0.75 kg/ha 7 DAS	1	1	0
Pyrazosulfuron-ethyl 0.03 kg/ha 7 DAS	0	0	0
Pretilachlor + pyrazosulfuron-ethyl 0.62 kg/ha 7 DAS	0	0	0
Pendimethalin + penoxsulam 0.625 kg/ha 7 DAS	1	2	0
Butachlor + penoxsulam 0.82 kg/ha 7 DAS	2	2	0

Rating scale: 0 - No injury, 1 - Slight injury, 2- Moderate injury, 3- Severe injury, 4- Very severe injury, 5-Complete destruction; DAS = days after seeding; DBS = days before seeding

The highest weedy rice control efficiency (WCE) of 73% was recorded with oxyfluorfen applied on the day of sowing (before rice seeding) (**Figure 1**). At 60 DAS and harvest the WCE was slightly reduced to 65%, yet it remained the most effective treatment among all herbicides evaluated. Among the combination herbicides used, butachlor + penoxsulam recorded the highest WCE of 46, 51 and 49% at 30, 60 DAS and harvest, respectively. This can be attributed to the pre-emergent action of the herbicide. In situations where the herbicide is applied to the soil surface, rice seedlings exhibit selective advantages as pre-germinated seeds are sown above the herbicide layer (Jose 2015). Weedy rice seedlings, along with other weed seedlings that germinate through the herbicide-treated stratum, fail to establish, leading to a reduction in the weed population. Oxyfluorfen application on the day of sowing was found superior to all other herbicides, likely due to the fact that all other herbicides were sprayed one week after sowing of rice and hence weedy rice could emerge during the period of 0 to 6 days after sowing rice seeds.

Almost a similar trend of WCE as that of weedy rice was observed in the case of other weeds also, except that butachlor + penoxsulam registered a higher WCE of 81% compared to 51% with respect to weedy rice. In the case of weeds other than weedy rice, the pre-emergent application of oxyfluorfen recorded the highest weed control efficiency of 92% at 60 DAS. The next best treatment was butachlor + penoxsulam where WCE was 81%. Pendimethalin + penoxsulam, pyrazosulfuron-ethyl and oxyfluorfen at 10 DAS registered WCE ranging from 70–75%. Butachlor at a lower dose of 0.625 kg/ha resulted in a poor WCE (23%) and high weed dry matter production, which led to severe crop-weed competition.

Phytotoxicity

Spraying of oxyfluorfen at 10 DAS showed a higher phytotoxicity (**Table 2**). The appearance of

tiny brownish spots and drying of leaf tips was noted. Oxyfluorfen is a selective herbicide that has both pre- and post-emergent action. The contact action of oxyfluorfen is well established, and it disrupts cell membranes and inhibits protoporphyrinogen oxidase, an enzyme essential for the biosynthesis of chlorophyll. This was in line with the findings of Abraham *et al*. (2010). Similarly, treatments such as oxyfluorfen on the day of sowing, butachlor and butachlor + penoxsulam also registered slight phytotoxicity. Butachlor generally induces mild toxicity in rice, leading to a notable reduction in pigment levels, along with alterations in chloroplast structure. Phytotoxicity of the combination herbicide butachlor + penoxsulam can also be attributed to the butachlor present in it, which constituted 38.8% of the active ingredient of the herbicide. At seven days after spraying also, the phytotoxicity score in all the treatments remained the same. However, by two weeks, plants in all treatments recovered, and no phytotoxicity could be observed.

Table 3. Effect of treatments on growth and yield parameters of wet-seeded rice

Treatment	No. of tillers/m^2		Panicles m^{-2}	Grains per panicle	Filled grains per panicle
	30 DAS	60 DAS			
Unweeded control	90.33^{f}	191.67^{i}	124.33^{i}	59.67^{f}	50.67^{e}
Weed free check (hand weeded)	285.79^{a}	571.67^{a}	471.00^{a}	113.00^{a}	108.00^{a}
Oxyfluorfen 0.15 kg/ha 0 DBS	258.72^{abc}	542.67^{b}	451.33^{b}	103.00^{ab}	95.67^{b}
Oxyfluorfen 0.15 kg/ha 10 DAS	245.95^{bc}	519.67^{c}	434.33^{c}	92.67^{bc}	85.33^{c}
Butachlor 1.25 kg/ha 7 DAS	237.67^{cd}	460.00^{f}	378.00^{ef}	84.67^{cd}	78.67^{c}
Butachlor 0.625 kg/ha 7 DAS	169.15^{e}	402.33^{h}	206.33^{h}	72.00^{e}	62.33^{d}
Pendimethalin 1.5 kg/ha 7 DAS	253.32^{abc}	481.00^{e}	389.33^{e}	86.33^{cd}	81.00^{c}
Pretilachlor 0.75 kg/ha 7 DAS	210.81^{d}	436.33^{g}	354.33^{g}	89.00^{cd}	83.67^{c}
Pyrazosulfuron-ethyl 0.03 kg/ha 7 DAS	238.43^{bcd}	455.67^{f}	374.33^{f}	84.67^{cd}	78.00^{c}
Pretilachlor + pyrazosulfuron-ethyl 0.62 kg/ha 7 DAS	237.02^{cd}	483.67^{e}	408.67^{d}	80.67^{de}	75.33^{c}
Pendimethalin + penoxsulam 0.625 kg/ha 7 DAS	242.29^{bcd}	484.67^{e}	414.67^{d}	86.67^{cd}	81.33^{c}
Butachlor + penoxsulam 0.82 kg/ha 7 DAS	272.9^{ab}	502.33^{d}	430.67c	92.00^{c}	85.00^{c}

In a column, means followed by common letters do not differ significantly at 5% level in Tukey's Test; *DAS = days after seeding; DBS = days before seeding

Table 4. Density (no./m^2) and biomass (g/m^2) of weeds other than weedy rice in wet-seeded rice at 60 DAS

Treatment*	Weed density (no./m^2)				Weed biomass (g/m^2)			
	G	S	B	Total	G	S	B	Total
Unweeded control	2.91^{a} (9.33)	6.14^{a} (37.33)	9.24^{a} (85.33)	11.5^{a} (132.00)	3.79^{a} (13.85)	2.60^{a} (6.29)	6.15^{a} (37.49)	7.62^{a} (57.63)
Weed free check (hand weeded)	0.71^{f} (0.00)	0.71^{e} (0.00)	0.71^{f} (0.00)	0.71^{g} (0.00)	0.71^{e} (0.00)	0.71^{d} (0.00)	0.71^{e} (0.00)	0.71^{g} (0.00)
Oxyfluorfen 0.15 kg/ha 0 DBS	1.34^{de} (2.33)	0.71^{e} (0.00)	1.94^{ef} (3.33)	2.47^{f} (5.67)	1.93^{d} (3.24)	0.71^{d} (0.00)	1.33^{de} (1.45)	2.26^{f} (4.70)
Oxyfluorfen 0.15 kg/ha 10 DAS	1.46^{de} (4.67)	1.76^{d} (2.67)	5.06^{bc} (25.33)	5.75^{bcd} (32.67)	2.70^{bc} (6.79)	0.83^{d} (0.19)	2.98^{cd} (8.91)	4.02^{de} (15.89)
Butachlor 1.25 kg/ha 7 DAS	2.26^{bc} (6.00)	2.92^{c} (8.00)	6.12^{b} (37.33)	7.18^{b} (51.33)	2.98^{b} (8.40)	1.61^{c} (2.08)	4.53^{abc} (20.15)	5.56^{bc} (30.55)
Butachlor 0.625 kg/ha 7 DAS	2.74^{ab} (9.00)	4.78^{b} (22.67)	8.34^{a} (69.33)	10.07^{a} (101.00)	3.53^{a} (12.02)	2.1^{b} (3.96)	5.33^{ab} (28.53)	6.69^{ab} (44.51)
Pendimethalin 1.5 kg/ha 7 DAS	1.56^{de} (4.33)	2.86^{c} (8.00)	4.91^{bc} (24.00)	6.04^{bc} (36.33)	2.52^{bc} (5.84)	1.52^{c} (1.84)	4.10^{bc} (16.60)	4.96^{cd} (24.28)
Pretilachlor 0.75 kg/ha 7 DAS	2.2^{bc} (6.00)	2.65^{cd} (6.67)	5.75^{bc} (33.33)	6.78^{b} (46.00)	2.97^{b} (8.33)	1.54^{c} (1.89)	4.50^{abc} (19.85)	5.52^{bc} (30.06)
Pyrazosulfuron-ethyl 0.03 kg/ha 7 DAS	1.23^{ef} (3.67)	0.71^{e} (0.00)	3.87^{cde} (14.67)	4.32^{de} (18.33)	2.37^{cd} (5.15)	0.71^{d} (0.00)	3.14^{c} (9.49)	3.88^{de} (14.64)
Pretilachlor + pyrazosulfuron-ethyl 0.62 kg/ha 7 DAS	1.86^{cd} (3.00)	0.71^{e} (0.00)	5.42^{bc} (29.33)	5.7^{bcd} (32.33)	2.17^{cd} (4.26)	0.71^{d} (0.00)	4.33^{bc} (18.71)	4.81^{cd} (22.97)
Pendimethalin + penoxsulam 0.625 kg/ha 7 DAS	1.87^{cd} (3.67)	0.71^{e} (0.00)	4.34^{bcd} (18.67)	4.75^{cde} (22.33)	2.36^{cd} (5.08)	0.71^{d} (0.00)	3.55^{bc} (12.17)	4.21^{cde} (17.24)
Butachlor + penoxsulam 0.82 kg/ha 7 DAS	1.34^{de} (2.33)	0.71^{e} (0.00)	2.92^{de} (8.00)	3.29^{ef} (10.33)	1.95^{d} (3.34)	0.71^{d} (0.00)	2.83^{cd} (7.52)	3.37^{ef} (10.86)

G - grasses, S - sedges, B - broadleaf weeds. $\sqrt{x+0.5}$ transformed values, original values in parenthesis. In a column, means followed by common letters do not differ significantly at 5% level in Tukey's Test.; DAS = days after seeding; DBS = days before seeding

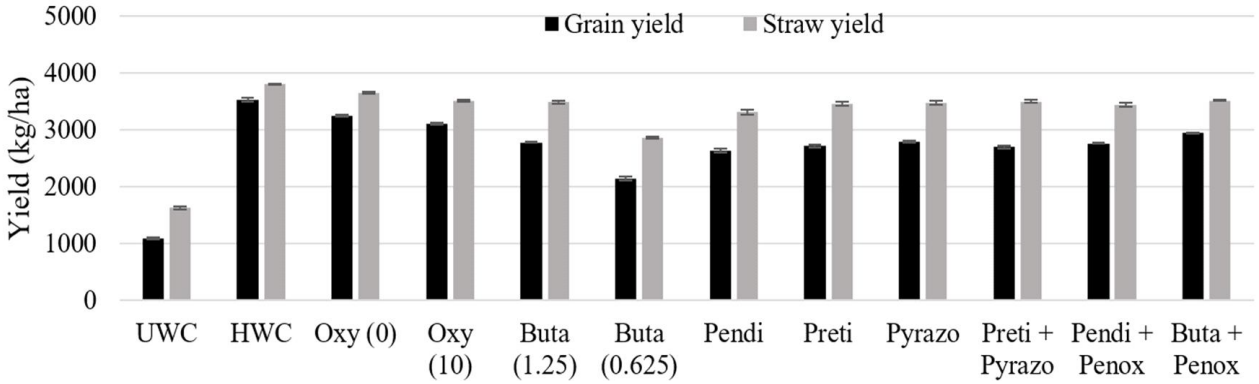


Figure 2. Effect of treatments on grain and straw yield of wet-seeded rice

UWC - unweeded control, HWC-weed-free check, Oxy (0) – oxyfluorfen at 0 DBS; Oxy (10) - oxyfluorfen at 10 DAS, Buta (1.25) - butachlor at 1.25 kg/ha; Buta (0.625) - butachlor (0.625 kg/ha), + penoxsulam; Pendi - pendimethalin, Preti - pretilachlor, Pyrazo – pyrazosulfuron-ethyl, Preti + Pyrazo - pretilachlor + pyrazosulfuron-ethyl, Pendi + Penox – pendimethalin + penoxsulam, and Buta + Penox - butachlor + penoxsulam; *DAS = days after seeding; DBS = days before seeding

Rice growth and yield

At all growth stages, oxyfluorfen 0 DBS and 10 DAS, butachlor + penoxsulam, and weed-free check registered taller plants with higher tiller number (**Table 3**). The higher tiller number with these treatments was due to the weed-free environment as evidenced by the lower density as well as dry matter production of weedy rice and other weeds (**Table 1** and **4**).

The efficient management of weeds favourably influenced yield parameters and yield (**Figure 2**). The weed-free check was statistically superior to all other treatments in terms of the number of panicles per unit area, number of filled grains per panicle, and grain and straw yield. The treatment of oxyfluorfen on the day of sowing resulted in almost double panicle number compared to the weedy check, which was inferior to all treatments due to severe competition induced by weedy rice and other weeds. Khodabaks (1999) observed that every increase of 1% population of weedy rice correlates with grain yield reduction of 6%. Among the herbicide treatments, oxyfluorfen on the day of sowing registered the highest grain yield (3247 kg/ha) and straw yield (3654 kg/ha), and was statistically superior to all other tested herbicides. Significant rice yield reduction (69%) was observed in the unweeded control when compared to weed free check. The oxyfluorfen applied before rice seeding recorded only 8% lesser yield than weed free (**Figure 2**).

The results demonstrated that the puddled soil application of oxyfluorfen 0.15 kg/ha immediately before broadcasting pre-germinated seeds in wet-seeded rice is highly effective for managing weedy rice, as it effectively prevents weedy rice germination. Oxyfluorfen 10 DAS and the premixed herbicide combination of butachlor + penoxsulam 7 DAS were identified as the next best treatment options for controlling weedy rice in wet-seeded rice.

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