Indian Journal of Weed Science (2025) **57**(2): 155–159
http://dx.doi.org/10.5958/0974-8164.2025.00026.6

RESEARCH ARTICLE

Weed control in direct-seeded rice with ready mix of penoxsulam + pendimethalin

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Received: 27 January 2025 | Revised: 26 April 2025 | Accepted: 30 April 2025

ABSTRACT

Diverse weed flora in direct-seeded rice (DSR) has underscored the need to identify broad-spectrum pre-emergence (PE) herbicide for managing weeds and to realize the yield potential of DSR. This study assessed weed dynamics and DSR productivity response to PE herbicide treatments, *viz*. penoxsulam 1% + pendimethalin 24% (penoxsulam + pendimethalin) at 500, 562.5 and 625 g/ha, pendimethalin at 750 g/ha and unsprayed control, during *Kharif* 2021 and 2022 in Department of Agronomy at Punjab Agricultural University, Ludhiana. Penoxsulam + pendimethalin 625 g/ha PE was most effective in controlling the weeds and reducing weeds biomass, mainly of grasses and sedges. During both years, no significant effect of PE herbicides on rice plant height was recorded except unsprayed control. Penoxsulam + pendimethalin 625 g/ha increased the effective tillers/m^2 of rice by 72% in 2021 and 87.8% in 2022 compared to unsprayed control. Moreover, penoxsulam + pendimethalin 625 g/ha significantly increased the mean grain yield of DSR by 187.0% (6.6 t/ha) compared with the unsprayed control (2.3 t/ha), but in 2022, it was at par to pendimethalin 750 g/ha (6.4 t/ha). Our study demonstrated that penoxsulam + pendimethalin 625 g/ha PE provided effective weed control by reducing weed biomass upto 30 DAS and enhanced productivity of DSR. However, need based post-emergence herbicide application needs to be done for better weed management in direct-seeded rice.

Keywords: Direct-seeded rice, Pendimethalin, Penoxsulam, Penoxsulam + pendimethalin, Weed management

INTRODUCTON

Globally, atleast 50% of the people rely on rice (*Oryza sativa* L.) as the primary food commodity (Dass *et al.* 2017). Over the past decade, India has produced 150 million tonnes of rice annualy from an area of 43 million hectares, with an average productivity of 3.2-3.7 tonnes/hectare (Singh and Ranguwal 2024). India should increase rice production by 3 million tonnes/year to ensure the continuing food security of its growing population (Dass *et al.* 2016). Puddled transplanted rice (PTR) is unsustainable in the long term due to demand of huge amount of labour, water, energy and deteriorates soil health due to repetitive tillage and puddling operations (Ojha and Kwatra 2014). Therefore, direct-seeded rice (DSR) is an emerging approach, to avoid the water-filled nurseries and transplanting by sowing rice seeds directly into the soil (Rao *et al.* 2017, Karthickraja *et al.* 2024). DSR technique saved 35-57% water over PTR (Bhushan *et al.* 2007). Yet, the area under DSR has not been expanded to the extent expected (Mohammad *et al.* 2018) mainly due to severe weed problem causing huge losses in rice productivity. Weeds could decrease DSR yield by 50 to 90% and the loss could be upto 100% (Bhullar *et al.* 2016). However, the intensity and duration of crop-weed competition governs the extent of crop yield loss (Sardana *et al.* 2017). The critical period of crop-weed competition in DSR is about 2-12 weeks which is far longer than PTR (Singh *et al.* 2014). For DSR success, weed management is considered as one of the key components.

In major rice growing Indian states, weeds are controlled by hand weeding and also by the application of herbicides. Under the conditions of growing labour shortage and high cost, hand weeding is labour intensive being much more costlier in DSR (Rao *et al.* 2007). The use of herbicides to control the weeds is easier and also less expensive (Chauhan 2012), therefore, the use of chemical weed control methods has become increasingly common practice in DSR cultivation. An ecological imbalance in weed shift, resistant biotypes and environmental deterioration results from the long-term use of herbicides of the same class in the same field (Hasan *et al.* 2022). It is crucial to identify broad-spectrum herbicides for sustainable weed management in DSR.

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Given the lacunae of the present weed management practices by the rice growers in relying solely on post-emergence herbicides, usage of pre-emergence application of herbicides as the weed management strategy should provide an initial advantage to reduce weed pressure, promote crop competitiveness, and enhance the economic benefits provided by DSR. Pre-emergence (PE) herbicides such as pendimethalin and penoxsulam have been well researched to control weeds (He *et al.* 2013) and were found to provide an efficient weed control with increased DSR yield. In this context, a herbicide which could provide broad spectrum control of weeds is desirable. The present field study was aimed to assess the efficacy of ready mix of penoxsulam 1% + pendimethalin 24% for weed management in DSR.

MATERIAL AND METHODS

A field experiment was conducted during *Kharif* 2021 and 2022 at Department of Agronomy, Punjab Agricultural University, Ludhiana to study the efficacy of ready-mix of penoxsulam 1% + pendimethalin 24% against weeds in direct-seeded rice. The climate in the Ludhiana (30°542 N and 75°482 E, 247 m above mean sea level) district of Punjab, India, is categorized by semi-arid with hot and dry early summer (March-June), hot and humid summer monsoon (July-September), mild winter (October-November) and very cold winter (December-February) seasons. The soil of the experimental site has a sandy loam texture. The evaluated treatments include: pre-emergence application (PE) of penoxsulam 1% + pendimethalin 24% (penoxsulam + pendimethalin) at 500, 562.5 and 625 g/ha, pendimethalin 750 g/ha PE and unsprayed control. The field experiment was conducted using randomized complete block design (RCBD) with four replications. Rice cv. PR 126 was sown on June 23rd, 2021 and June 9th, 2022 with seed rate of 20 kg/ha at 20 cm rows apart. All treatments were sprayed in moist soil using 500 litres of water/ha by using battery operated knapsack sprayer fitted with flood jet nozzle. The recommended package of practices, except weed control treatments, were followed to raise the crop. Bispyribac-sodium 25 g/ha was sprayed as post-emergence application (PoE) at 30 days after seeding (DAS) (after the weed data recording) in all PE herbicide treatments as blanket spray.

Data on weeds were recorded with quadrat (50cm × 50cm) from two locations in each plot. The plants were then placed them separately in brown paper bags to dry in the sun. After proper drying off the excess moisture, these paper bags were placed in an oven at 70±2°C for 72 hours until the weed samples attained a constant weight. The statistical analysis of the parameters measured was done by using CPCS-1 software, version 3.2.3 (Cochran and Cox 1957). The weed density and weed dry weight (weed biomass) data were subjected to square root transformation to normalize their distribution.

RESULTS AND DISCUSSION

Effect on weed density

All the herbicide treatments significantly influenced the density of weeds at 15 and 30 DAS over unsprayed control. Penoxsulam + pendimethalin 625 g/ha PE provided effective control of weeds including *Echinochloa colona, Digitaria sanguinalis* and *Cyperus iria* in 2021 and 2022. Weed density of grasses and sedge at both stages decreased with increase in dose of penoxsulam + pendimethalin during both the years. Density of *E. colona* at 15 DAS and *D. sanguinalis* at 15 and 30 DAS with pendimethalin 750 g/ha, penoxsulam + pendimethalin 562.5 and 625 g/ha were statistically at par with each other but significantly lower than penoxsulam + pendimethalin 500 g/ha and unsprayed control. Moreover, in 2021, penoxsulam + pendimethalin 625 g/ha significantly reduced the density of *E. colona* at 30 DAS than all other herbicide treatments and unsprayed control. In 2022, *E. colona* density with penoxsulam + pendimethalin 625 g/ha was statistically at par to pendimethalin 750 g/ha and significantly lower than all other herbicide treatments. During both years, at 15 DAS, penoxsulam + pendimethalin 625 g/ha resulted in reduced density of *C. iria* as compared to other herbicide treatments, but was statistically at par with lower dose of penoxsulam + pendimethalin 562.5 g/ha. In 2022, density of *C. iria* at 30 DAS with pendimethalin 750 g/ha was also statistically at par to penoxsulam + pendimethalin 625 g/ha but significantly lower than all other herbicide treatments. However, penoxsulam + pendimethalin 625 g/ha provided better control of *C. iria* population till 30 DAS as compared to other herbicide treatments (**Table 1**). Better performance of ready mix herbicide was known in controlling all types of weeds and this was due to synergistic effect of these herbicides. Pendimethalin inhibit microtubulin synthesis which are essential in the formation of cell wall microfibrils that stops cell enlargement and chromosome movement during mitosis in germinating seeds and young weed shoots (Appleby and Valverde 1989) and penoxsulam prevents producing acetolactate synthase, a necessary enzyme for plant growth, consequently results in less weed density. The results are in line with Yadav *et al.* (2008) and Mishra *et al.* (2007) who reported an excellent control of grasses and sedges with penoxsulam in PTR. Mahajan and Chauhan (2008) also reported the reduced density of *E. colona* and *Cyperus iria* with the application of penoxsulam as compared to control. Singh *et al*. (2019) also reported that pendimethalin 2 kg/ha provided control of weeds in DSR.

Effect on weed biomass

Biomass of grasses and sedge decreased with the increase in dose of penoxsulam + pendimethalin during both the years. Penoxsulam + pendimethalin 625 g/ha recorded less grass weeds biomass at 30 DAS than its lower dose of 500 and 562.5 g/ha, pendimethalin 750 g/ha and unsprayed control except in 2021 where biomass with penoxsulam + pendimethalin 562.5 and 625 g/ha were statistically at par to each other. During both years, penoxsulam + pendimethalin 500, 562.5 and 625 g/ha recorded significantly less biomass of sedges at 30 DAS over pendimethalin 750 g/ha and unsprayed control (**Table 2**). PE herbicides applied on the soil surface are absorbed by the soil colloids and provide a thin layer of herbicidal protection. The new emerging shoots of weeds contain meristematic tissues which absorb the chemical, causing them to exhibit some phytotoxic symptoms and decrease their biomass (Onwuchekwa-Henry *et al*. 2023). Khare *et al*. (2014) reported the lowest biomass of grass weeds in penoxsulam 25 g/ha in rice. Singh *et al*. (2019) recorded no biomass for all weed species with 2.0 kg/ha pendimethalin, whereas, *Leptochloa chinensis* and *D*. *aegyptium* failed to emerge in 1.0 kg/ha pendimethalin and produced no weed biomass at these application rates in DSR. Onwuchekwa-Henry *et al.* (2023) also reported that shoot dry weight of *E. crusgalli* was effectively controlled by pendimethalin 2 kg/ha.

Effect on rice growth and yield

During both years, all the herbicide treatments produced similar plant height but significantly higher than unsprayed control. Penoxsulam + pendimethalin 625 g/ha recorded significantly more number of effective tiller/m^2 as compared to lower doses of penoxsulam + pendimethalin 562.5 and 500 g/ha, except in 2022, where it was also statistically at par with pendimethalin 750 g/ha (Table 3). Weed free conditions at initial stages for proper growth and development of rice plants allowed the crop to absorb available nutrients, water and sunlight for its growth and tillering behavior and ultimately enhanced the

Table 1. Effect of different weed management treatments on weed density at 15 and 30 DAS in direct-seeded rice during 2021 and 2022

Treatment	Dose (g/ha)	Weed density* (no./m^2)											
		Grasses								Sedge			
		Echinochloa colona				*Digitaria sanguinalis*				*Cyperus iria*			
		15 DAS		30 DAS		15 DAS		30 DAS		15 DAS		30 DAS	
		2021	2022	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
Penoxsulam + pendimethalin	500	2.5(5)	3.9(15)	3.5(12)	4.0(15)	2.7(6)	4.4(19)	3.3(11)	4.1(16)	2.7(7)	3.2(9)	4.6(21)	4.3(18)
Penoxsulam + pendimethalin	562.5	1.2(0.7)	1.3(0.7)	3.0(8)	3.5(11)	1.0(0)	1.1(0.3)	2.4(5)	3.0(8)	1.0(0)	1.4(1)	3.8(14)	4.5(19)
Penoxsulam + pendimethalin	625	1.0(0)	1.0(0)	2.2(4)	2.6(6)	1.0(0)	1.0(0)	2.4(5)	2.4(5)	1.0(0)	1.2(0.7)	2.9(7)	3.7(13)
Pendimethalin	750	1.0(0)	1.5(1)	3.5(12)	2.9(8)	1.0(0)	1.0(0)	2.4(5)	3.1(9)	4.1(16)	4.0(15)	4.5(20)	4.0(15)
Unsprayed Control	-	4.8(22)	4.8(22)	7.3(53)	4.8(23)	6.3(39)	4.7(21)	4.5(19)	4.6(20)	5.4(28)	6.4(41)	6.7(44)	7.0(48)
LSD (p=0.05)	-	0.29	0.68	0.61	0.77	0.45	0.54	0.48	0.77	0.96	0.71	0.89	0.59

*Figures in parentheses are original means. Data were subjected to square root transformation; DAS = days after seeding

Table 2. Effect of weed management treatments on weed biomass at 30 DAS (before POST application) in direct-seeded rice during 2021 and 2022

Treatment	Dose (g/ha)	Weed biomass* (g/m^2)			
		Grasses		Sedge	
		2021	2022	2021	2022
Penoxsulam + pendimethalin	500	3.92 (14)	4.51 (19)	3.46 (11)	4.35 (18)
Penoxsulam + pendimethalin	562.5	2.64 (6)	3.11 (9)	3.31 (10)	4.36 (18)
Penoxsulam + pendimethalin	625	2.29 (4)	2.31 (4)	3.04 (8)	4.00 (15)
Pendimethalin	750	3.74 (13)	3.41 (11)	5.66 (31)	5.23 (26)
Unsprayed control	-	12.13 (146)	11.76 (137)	10.83 (116)	11.30 (127)
LSD (p=0.05)	-	0.49	0.29	0.44	0.88

*Figures in parentheses are original means. Data were subjected to square root transformation; DAS = days after seeding

Table 3. Effect of weed management treatments on growth and grain yield of direct-seeded rice during 2021 and 2022

Treatment	Dose (g/ha)	Plant height (cm)		Effective tillers/m^2		Grain yield (t/ha)		Mean grain yield (t/ha)
		2021	2022	2021	2022	2021	2022	
Penoxsulam + pendimethalin	500	99.80	98.37	322	325	5.3	5.6	5.4
Penoxsulam + pendimethalin	562.5	99.13	101.07	338	330	6.4	6.1	6.3
Penoxsulam + pendimethalin	625	98.43	98.43	344	338	6.7	6.5	6.6
Pendimethalin	750	99.87	98.97	334	335	6.3	6.4	6.4
Unsprayed control	-	93.47	92.37	200	180	2.6	2.0	2.3
LSD (p=0.05)	-	3.56	2.73	5	7	0.3	0.4	-

effective tillers/m^2 (Saha and Rao 2010). During both years and in pooled mean, penoxsulam + pendimethalin 625 g/ha recorded significantly higher rice grain yield than its lower doses 500 and 562.5 g/ha. Moreover, in 2022, rice grain yield (6.5 t/ha) recorded with penoxsulam + pendimethalin 625 g/ha was also statistically at par with pendimethalin 750 g/ha (6.4 t/ha) (**Table 3**). Pooled mean grain yield of penoxsulam + pendimethalin 625 g/ha was 187.0% higher over unsprayed control due to more numbers of effective tillers/m^2 which was consequently responsible for higher grain yield in rice. Reduced competition for space, light, moisture and nutrients between crop and weed flora along with effective suppression of weeds by these pre-emergence herbicides has helped in obtaining higher productivity (Singh *et al*. 2019). Efficiency of penoxsulam in controlling weeds and increasing grain yield of rice was also reported by Mishra *et al.* (2007) and Jason *et al.* (2007). Khare *et al.* (2014) also reported the highest grain yield of rice under penoxsulam at 25 g/ha. Onwuchekwa-Henry *et al.* (2023) also reported that tillers/m^2 and grain yield of rice were significantly increased by pendimethalin 1.5 kg/ha over control.

A negative linear correlation between weed biomass with rice grain yield showed that as weed biomass increased, grain yield of DSR decreased linearly (**Figure 1**). This correlation showed that presence of weeds at crop establishment stage adversely affected rice growth by competing for resources like nutrients, sunlight and water. Grain yield of DSR showed strong negative correlation with weed biomass at 30 DAS (R^2 = - 0.95), indicating that weed biomass accounted for 95% of the variation in DSR grain yield. The findings are supported by the research conducted by Roy *et al.* (2024).

Based on two year field study, it may be concluded that penoxsulam 1% + pendimethalin 24% at 625 g/ha PE provided effective control of annual weeds. However, post-emergence herbicide application as per the weed flora needs to be done for better weed control in DSR which proved to be a key in promoting sustainable agriculture and safeguarding food security.

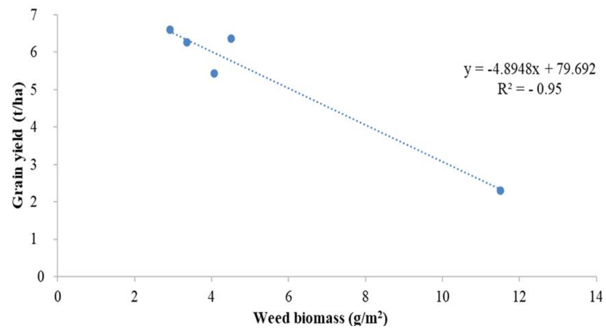

Figure 1. Relationship of grain yield with weed biomass at 30 DAS

ACKNOWLEDGEMENT

The authors thank M/s Rallis India Ltd. for providing samples of penoxsulam 1% + pendimethalin 24%.

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