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Research Paper

Effective weed management under Direct Seeded Rice through use of florpyrauxifen-benzyl plus cyhalofop butyl as post-emergence herbicide in Northwestern India

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ABSTRACT

Direct-seeded rice (DSR) is a viable alternative for unsustainable puddled transplanting method of raising rice crop but presence of the large weed pressure of diverse flora restricts its adoption on a large scale. A two-year field experiment was conducted to evaluate the bio-efficacy of florpyrauxifen-benzyl 20 g/L plus cyhalofop butyl 100 g/L at 120, 150 and 180 g a.i./ha, florpyrauxifen-benzyl 2.5 EC at 31.25 g a.i./ha, cyhalofop butyl 10 EC at 150 g a.i./ha, penoxsulam 1.02% plus cyhalofop butyl 5.1% at 135 g a.i./ha, bispyribac sodium 10 SC at 25 g a.i./ha and unsprayed control during *kharif* 2019 and 2020 in Department of Agronomy at Punjab Agricultural University, Ludhiana, Punjab, India. All post-emergence herbicides resulted in reduction in weed density and biomass as compared to unsprayed control treatment. Florpyrauxifen-benzyl 20 g/L plus cyhalofop butyl 100 g/L at 150 g a.i./ha was the most effective in controlling the population of *Echinochloa crus-galli*, *Cyperus iria* and *Caesulia axillaris*, that resulted in increase in effective tillers by 20.6% in 2019 and 15.9% in 2020 over unsprayed control. Moreover, florpyrauxifen-benzyl 20 g/L plus cyhalofop butyl 100 g/L at 150 g a.i./ha significantly increased the grain yield of DSR by 60.4% in 2019 and 82.0% in 2020 as compared to unsprayed control. Thus, post-emergence application of florpyrauxifen-benzyl 20 g/L plus cyhalofop butyl 100 g/L at 150 g a.i./ha provided an effective control of complex weed flora comprising of grasses, broadleaf weeds and sedges and enhanced the productivity of DSR.

Key words: Broadleaf weeds, Dry seeded rice, Grasses, Grain yield, Sedges, Weed biomass

Rice (*Oryza sativa*) is a major cereal crop and staple diet of more than 50% of the world's population. With an average productivity of 3.2-3.7 t/ha, India has produced 150 million tonnes of rice annually from an area of 43 million hectares over the last decade (Singh and Ranguwal, 2024). Puddled transplanted rice (PTR) is a pre-dominant conventional production technology but it is highly unsustainable in the long run as it requires huge amount of water, labour and energy and degrades soil health because of puddling and repetitive tillage operations (Ojha and Kwatra, 2014). Singh *et al.,* (2022) reported rising the issues of fresh water scarcity across the world and increased labour costs due to movement of rural labour workers to cities (Chauhan, 2012). Therefore, direct-seeded rice (DSR) has shown promising technique to avoid the water-filled nurseries and transplanting by sowing rice seeds directly into the soil and a potential alternative of PTR (Karthickraja *et al.,* 2024). The DSR production system saves 10-20% of water (Anonymous *et al.,* 2025) and reduces the labour requirement (11-66%) over PTR (Rashid *et al.,* 2009).

The area under DSR has not been expanded mainly due to more weed pressure and improper weed management practices (Mohammad *et al.,* 2018). Around 50 to 90% yield of DSR could decreased by weeds and the loss could be upto 100% (Kaur *et al.,* 2024). The extent of loss in yield is governed by the intensity and duration of crop-weed competition (Sardana *et al.,* 2017). The critical period of crop-weed competition in DSR *i.e.* 2-12 weeks, is longer than PTR (Singh *et al.,* 2014). Weeds are mainly controlled by hand weeding in Asian countries. Due to labour shortage and high wages, hand weeding being labour-intensive is five times more costlier (Rao *et al.,* 2007). Since use of herbicides are more efficient, simple to use, offer selective control, require less labour and are less expensive, their use is gaining popularity among DSR farmers (Chauhan, 2012).

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Farmers generally use either pre- or post-herbicide application in DSR. However, application of one type (pendimethalin or bispyribac sodium) of herbicide fail to control complex weed flora (Chauhan and Opeña, 2012; Kaur *et al*., 2023; Patidar and Kaur, 2024). Also, continuous use of herbicides with limited mode of action resulted in evolution of herbicide resistance in many weeds (Becerra-Alvarez *et al.,* 2023). For effective weed control of complex weed flora and to avoid shifts towards problematic weed species, it is a necessity to use herbicide-mixture with broad-spectrum efficacy (Kaur *et al*., 2023). For post-emergence control of broadleaf weeds and sedges in DSR, premix of metsulfuron plus chlorimuron 4 g/ha or 2,4-D amine salt 725 g/ha, an auxin mimics are efficient and economical herbicides (Patidar and Kaur, 2024). In contrast to 2,4-D, florpyrauxifen-benzyl has different binding site of action that shows strong binding affinity in the auxin signaling system, and has a broad spectrum efficacy of weed control including grasses, sedges and broadleaf weeds in rice (Miller and Norsworthy, 2018). Furthermore, florpyrauxifen-benzyl can be used to control weeds which have evolved resistance to acetolactate and enolpyruvyl shikimate phosphate synthase inhibitors (Baltazar and De Datta, 2023). Cyhalofop butyl is an ACCase inhibiting post-emergence graminicide used to control grass weeds in rice (Ottis *et al.,* 2005). For sustainable weed management, use of combined or mixed two or more herbicide molecules with different mode of action is essential for broad-spectrum weed control efficiency. Integration of florpyrauxifen-benzyl and cyhalofop butyl with two different modes of action provides an opportunity for control of diverse weed flora in a single application. The use of this premix at 20-25 DAS control the weeds in the critical period of crop-weed competition in DSR. Thus, our hypothesis in this field experiment aimed to evaluate the bio-efficacy and effective use rates of florpyrauxifen-benzyl 20 g/L plus cyhalofop butyl 100 g/L for weed control in DSR in northwestern India.

MATERIALS AND METHODS

An experiment was conducted during *kharif* 2019 and 2020 at Department of Agronomy, Punjab Agricultural University, Ludhiana, Punjab, India to assess the bio-efficacy of florpyrauxifen-benzyl 20 g/L plus cyhalofop butyl 100 g/L against the weeds in DSR production system. The experimental site in Ludhiana district of Punjab, India, is situated at 30°54′ N and 75°48′ E, 247 m above MSL, which is categorized by semi-arid with hot and dry early summer from March to June, hot and humid summer monsoon from July to September, mild winter from October to November and very cold winter from December to February. During the year, mean maximum and minimum temperatures shows significant fluctuations. The minimum temperature during winter season falls below 4^{o}C while during summer season, temperature exceeds 38^{o}C and many a time reaches 47^{o}C. Average annual rainfall of Ludhiana district of Punjab is 759 mm, 75-80% of which is received during the monsoon period. The soil of the experiment site has a sandy loam texture (64.65% sand, 17.31% silt and 18.04% clay) with a pH of 6.7 and EC of 0.17 dS/m. The soil fertility status was low in available nitrogen (218.7 kg/ha), medium in available phosphorus (13.6 kg/ha) and available potassium (179.1 kg/ha).

The field experiment was conducted in three replications using randomized complete block design (RBD). Treatments comprised of florpyrauxifen-benzyl 20 g/L plus cyhalofop butyl 100 g/L at 120, 150 and 180 g a.i./ha, florpyrauxifen-benzyl 2.5 EC at 31.25 g a.i./ha, cyhalofop butyl 10 EC at 150 g a.i./ha, penoxsulam 1.02% plus cyhalofop butyl 5.1% at 135 g a.i./ha, bispyribac sodium at 25 g a.i./ha and unsprayed control (Table 1). Ready mix of florpyrauxifen-benzyl 20 g/L plus cyhalofop butyl 100 g/L was sponsored by Corteva Agriscience Ltd. Rice cv. PR 126 was sown on 5 June 2019 and 2 June 2020 at row spacing of 20 cm using seed rate of 20 kg/ha. All treatments were sprayed by using 375 litres/ha of water by battery operated knapsack sprayer fitted with flat fan nozzle at

Table 1. Treatment details of the present experimentation.

Treatment	Active Ingredient Dose (g a.i./ha)	Formulation dose (mL/ha)
Florpyrauxifen-benzyl 20 g/L plus cyhalofop butyl 100 g/L	120 (20 + 100)	1,000
	150 (25 + 125)	1,250
	180 (30 + 150)	1,500
Florpyrauxifen-benzyl 2.5 EC	31.25	1,250
Cyhalofop butyl 10 EC	150	1,500
Penoxsulam + cyhalofop butyl 6 OD	135	2,250
Bispyribac sodium 10 SC	25	250
Unsprayed control	-	-

2-4 leaf stage of weeds at 20 DAS. The recommended package of practices were followed to raise the crop, except weed control treatments. The recommended dose of phosphorus (30 kg P_2O_5/ha) as single super phosphate, potassium (30 kg K_2O/ha) as muriate of potash and zinc sulphate heptahydrate (62.5 kg/ha) were applied at the time of seedbed preparation by broadcasting. Nitrogen 187.5 kg/ha in the form of urea was applied as broadcast in three equal splits at 4, 6 and 9 weeks of sowing.

Data on weeds was recorded from two locations in each plot with quadrat (50 cm × 50 cm) at 15, 30 and 45 days after application (DAA). The different weed species were identified, counted and cut at collar portion of the plants. The plants were then placed separately in brown paper bags to dry in the sun for 3-5 days. After the excess moisture was properly dried off, these paper bags were placed in an oven at 70±2°C for 72 hours until the weed samples achieved a constant weight, which was considered the weed biomass of the respective weed species. For analysis and interpretation of weed density and weed biomass, the mean of both quadrates was converted into numbers/m^2 and g/m^2, respectively. Effective tillers and grain yield of direct seeded rice were recorded at crop harvest. The statistical analysis of the parameters measured was done by using CPCS-1 software, version 3.2.3 (Cheema and Singh, 1991). To determine the significant differences between means, Fisher's Least Significant Difference (LSD) test was employed at a 5% probability level (Cochran and Cox, 1957). The weed density and weed biomass data were subjected to square root transformation before analysis to normalize their distribution.

RESULTS AND DISCUSSION

Effect on weed density

All the herbicide treatments significantly decreased density of grass (*Echinochloa crus-galli*), sedge (*Cyperus iria*) and broadleaf weed (*Caesulia axillaris*) at 15, 30 and 45 DAA over unsprayed control (Table 2). Weedy check plots recorded higher weed density of *E. crus-galli* at 15 DAA (228.6% and 290.0%), 30 DAA (258.3% and 160%) and 45 DAA (315.4% and 217.6%) in 2019 and 2020, respectively over application of florpyrauxifen-benzyl 20 g/L plus cyhalofop butyl 100 g/L at 150 g a.i./ha. Application of florpyrauxifen-benzyl 20g/L plus cyhalofop butyl 100g/L at 180 g a.i./ha, penoxsulam 1.02% plus cyhalofop butyl 5.1% at 135 g a.i./ha and bispyribac sodium at 25 g a.i./ha resulted in statistically at par and significantly lower weed density of *C. iria* than other herbicide treatments and unsprayed control. Application of premix of florpyrauxifen-benzyl 20g/L plus cyhalofop butyl 100g/L at 150 and 180 g a.i./ha recorded statistically similar control of *Caesulia axillaris* at all stages. Significantly higher weed density of *Cyperus iria* and *Caesulia axillaris* were recorded in standalone application of florpyrauxifen-benzyl 2.5 EC and cyhalofop butyl 10 EC as compared to its ready mix combination (florpyrauxifen-benzyl 20 g/L plus cyhalofop butyl 100 g/L).

Weedy check plots recorded higher density of *Caesulia axillaris* at 15 DAA (131.3% and 194.1%), 30 DAA (158.8% and 155.0%) and 45 DAA (218.8% and 264.3%) in 2019 and 2020, respectively as compared to florpyrauxifen-benzyl 20 g/L plus cyhalofop butyl 100 g/L at 150 g a.i./ha (Table 2). Following the treatmeant with florpyrauxifen-benzyl plus cyhalofop butyl, weeds exhibit auxin like symptoms, such as wilting, epinasty, leaf malformation, tissue swelling, stunting, and necrosis which consequently reduce the density of weeds (Bell *et al.,* 2015). The premix of florpyrauxifen-benzyl 20 g/L plus cyhalofop butyl 100 g/L at 150 g a.i./ha was effective in reducing the density of diverse weed flora. Jabran *et al.,* (2012) observed that a herbicide molecule with single mode of action is not sufficient to control diverse weeds present in rice production systems. The diverse weed flora in rice require two or more herbicides for satisfactory control of a variety of weed species (Gianessi *et al.,* 2002). Application of combination herbicide products with different modes of action, offers the effective solution for broad spectrum weed control in early or mid-season (Krishnamurthy *et al.,* 2010; Mahapatra *et al.,* 2023). Sreedevi et al. (2020) reported that application of florpyrauxifen-benzyl plus cyhalofop butyl at 150 g a.i./ha recorded lowest total weed density that was statistically at par with application of florpyrauxifen-benzyl at 30 g a.i./ha in aerobic rice.

Effect on weed biomass

The biomass of *E. crus-galli*, *Cyperus iria* and *Caesulia axillaris* at 15, 30 and 45 DAA were significantly decreased by all the herbicide treatments over unsprayed control (Table 3). Application of florpyrauxifen-benzyl 20 g/L plus cyhalofop butyl 100 g/L at 180 g a.i./ha, cyhalofop butyl 10 EC at 150 g a.i./ha , penoxsulam 1.02% plus cyhalofop butyl 5.1% at 135 g a.i./ha and bispyribac sodium at 25 g a.i./ha recorded statistically similar and significantly lower biomass of *E. crus-galli* at 15, 30 and 45 DAA over all other herbicide treatments and unsprayed control. The premixes of florpyrauxifen-benzyl 20 g/L plus cyhalofop butyl 100 g/L at 180 g a.i./ha and penoxsulam 1.02% plus cyhalofop butyl 5.1% at 135 g a.i./ha performed statistically at par to bispyribac sodium at 25 g a.i./ha for control of *Cyperus iria,* and these herbicides recorded significantly lower biomass at all stages over other herbicide treatments and unsprayed control. Application of florpyrauxifen-benzyl 20 g/L plus cyhalofop butyl 100 g/L

Table 2. Effect of different herbicide treatments on periodic weed density in direct seeded rice during *kharif* 2019 and 2020

Treatments	Dose (g a.i./ha)	*Echinochloa crus-galli* (No./m^2) 15 DAA		30 DAA		45 DAA		*Cyperus iria* (No./m^2) 15 DAA		30 DAA		45 DAA		*Caesulia axillaris* (No./m^2) 15 DAA		30 DAA		45 DAA	
		2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
Florpyrauxifen-benzyl 20 g/L	120	1.7	1.3	2.6	2.2	3.2	2.2	3.1	3.6	2.2	3.8	2.9	3.6	3.3	3.3	3.9	3.8	3.5	3.5
plus cyhalofop butyl 100 g/L		(2)	(1)	(6)	(4)	(9)	(4)	(8)	(12)	(4)	(13)	(7)	(12)	(10)	(9)	(14)	(13)	(11)	(11)
	150	1.4	1.0	1.2	1.5	1.3	1.7	1.7	2.1	1.8	2.2	1.9	1.8	1.6	1.7	1.7	2.0	1.6	1.4
		(1)	(1)	(1)	(1)	(1)	(2)	(2)	(3)	(2)	(4)	(2)	(2)	(2)	(2)	(3)	(4)	(2)	(1)
	180	1.0	1.2	1.2	1.2	1.1	1.0	2.1	1.0	1.2	1.0	1.7	1.0	1.0	1.4	1.0	1.0	1.2	1.0
		(0)	(1)	(1)	(1)	(0)	(0)	(3)	(0)	(1)	(0)	(2)	(0)	(0)	(1)	(0)	(0)	(1)	(0)
Florpyrauxifen-benzyl 2.5 EC	31.25	2.3	1.0	2.9	1.2	2.8	1.2	2.0	3.3	2.4	3.1	3.5	3.4	2.3	3.3	2.7	3.1	3.1	3.6
		(4)	(0)	(7)	(1)	(7)	(1)	(3)	(10)	(5)	(8)	(11)	(10)	(4)	(10)	(7)	(8)	(9)	(12)
Cyhalofop butyl 10 EC	150	1.0	1.0	1.2	1.0	1.3	1.0	5.06	5.4	6.0	4.8	6.9	6.0	3.7	4.9	4.8	4.7	5.3	5.3
		(0)	(0)	(1)	(0)	(1)	(0)	(24)	(27)	(35)	(22)	(47)	(35)	(13)	(23)	(22)	(21)	(27)	(28)
Penoxsulam + cyhalofop butyl 6 OD	135	1.0	1.0	1.0	1.5	1.0	1.5	1.2	1.8	1.0	1.4	1.2	1.2	2.6	2.2	3.5	1.7	4.3	1.7
		(0)	(0)	(0)	(1)	(0)	(1)	(1)	(3)	(0)	(1)	(1)	(1)	(6)	(4)	(11)	(2)	(17)	(2)
Bispyribac sodium 10 SC	25	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	2.8	1.9	2.9	1.7	3.8	2.0
		(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(7)	(2)	(7)	(2)	(14)	(3)
Unsprayed control	-	4.6	3.9	4.3	3.9	5.4	5.4	4.4	5.2	4.8	5.6	5.7	6.4	3.7	5.0	4.4	5.1	5.1	5.1
		(20)	(14)	(18)	(14)	(28)	(28)	(18)	(25)	(22)	(30)	(32)	(38)	(13)	(24)	(18)	(25)	(25)	(25)
SEm±	-	0.2	0.2	0.3	0.2	0.2	0.2	0.2	0.3	0.2	0.2	0.3	0.2	0.3	0.3	0.3	0.3	0.3	0.4
CD (P=0.05)	-	0.7	0.6	0.8	0.5	0.5	0.7	0.6	0.8	0.7	0.7	0.8	0.6	0.8	0.8	1.0	0.8	0.8	1.3

*Figures in parentheses are original means. Data were subjected to square root transformation. *DAA-Days after application

at 150 and 180 g a.i./ha recorded statistically similar and significantly lower biomass of *Caesulia axillaris* than other herbicide treatments and unsprayed control at 15 DAS during both years. At 30 and 45 DAA, application of florpyrauxifen-benzyl 20 g/L plus cyhalofop butyl 100 g/L at 180 g a.i./ha recorded significantly lower biomass of *Caesulia axillaris* as compared to other hebicides and unsprayed control.

The premix of florpyrauxifen benzyl plus cyhalofop butyl had lower weed biomass than other herbicides. Lower weed biomass was attained due to efficient control of grasses and broadleaf weeds. Florpyrauxifen-benzyl 20 g/L plus cyhalofop butyl 100 g/L at 180 g a.i./ha resulted in lower biomass of *E. crus-galli* (with weed control efficiency of 100 and 100% at 15 DAA; 96 and 99% at 30 DAA and 100 and 100% at 45 DAA) *Cyperus iria* (with weed control efficiency of 89 and 100% at 15 DAA; 94 and 97% at 30 DAA and 100 and 100% at 45 DAA) and *Caesulia axillaris* (with weed control efficiency of 100 and 97% at 15 DAA; 100% and 95% at 30 DAA and 95 and 92% at 45 DAA) during 2019 and 2020, respectively than weedy check plots. Kaur *et al.* (2023) also reported application of ready mix herbicide produced lower weed biomass due to effective control of complex weed flora by two different modes of action compared to application of single herbicide. The activity of florpyrauxifen benzyl mixture for control of grasses has also been reported earlier (Miller and Norsworthy, 2018). This combination restricts the emergence and growth of weeds, which resulted in lower weed dry matter production, leading to higher weed con-

Table 3. Effect of different herbicide treatments on periodic weed biomass in direct seeded rice during *kharif* 2019 and 2020.

Treatment	Dose (g a.i./ha)	*Echinochloa crus-galli* (g/m^2)						*Cyperus iria* (g/m^2)						*Caesulia axillaris* (g/m^2)					
		15 DAA		30 DAA		45 DAA		15 DAA		30 DAA		45 DAA		15 DAA		30 DAA		45 DAA	
		2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
Florpyrauxifen-benzyl 20 g/L	120	4.0	3.6	4.2	3.9	3.9	4.4	3.9	1.0	4.1	5.4	6.3	6.1	4.0	3.9	5.4	4.8	5.4	6.6
plus cyhalofop butyl 100 g/L		(15)	(12)	(16)	(14)	(14)	(18)	(14)	(0)	(15)	(28)	(38)	(35)	(15)	(14)	(29)	(22)	(29)	(42)
	150	2.0	2.3	2.8	2.3	2.1	2.6	2.3	1.0	2.5	2.9	2.3	2.4	1.8	1.8	3.0	3.4	3.2	4.2
		(8)	(5)	(8)	(4)	(3)	(6)	(5)	(0)	(6)	(7)	(4)	(5)	(3)	(3)	(10)	(10)	(10)	(17)
	180	1.0	1.0	2.2	1.4	1.0	1.0	2.1	1.0	1.9	1.7	1.0	1.0	1.0	1.4	1.0	1.7	1.7	2.9
		(0)	(0)	(4)	(1)	(0)	(0)	(4)	(0)	(3)	(2)	(0)	(0)	(0)	(1)	(0)	(2)	(3)	(7)
Florpyrauxifen-benzyl 2.5 EC	31.25	3.9	4.7	4.4	4.6	5.2	5.0	2.8	3.4	3.5	4.0	5.7	6.1	3.9	3.4	5.4	4.0	6.8	
		(14)	(21)	(18)	(20)	(26)	(23)	(7)	(10)	(11)	(15)	(31)	(36)	(15)	(10)	(28)	(15)	(45)	(83)
Cyhalofop butyl 10 EC	150	1.0	1.0	1.0	1.0	1.7	1.0	6.5	5.8	6.8	6.6	8.0	7.0	4.8	6.1	7.1	6.7	7.6	
		(0)	(0)	(0)	(0)	(2)	(0)	(41)	(32)	(45)	(43)	(63)	(47)	(22)	(35)	(50)	(44)	(57)	(47)
Penoxsulam + cyhalofop butyl 6 OD	135	1.0	1.0	1.0	1.2	1.0	1.5	1.4	1.0	1.0	1.7	1.0	1.0	3.6	4.4	4.9	2.0	4.8	2.4
		(0)	(0)	(0)	(1)	(0)	(1)	(1)	(0)	(0)	(3)	(0)	(0)	(12)	(18)	(23)	(5)	(22)	(6)
Bispyribac sodium 10 SC	25	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	4.8	4.2	5.2	2.0	5.7	2.8
		(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(0)	(21)	(16)	(26)	(5)	(32)	(8)
Unsprayed control	-	7.2	9.1	9.9	9.8	10.7	10.5	6.0	7.8	7.3	8.3	8.5	8.8	5.8	6.4	7.3	6.6	8.1	9.3
		(51)	(81)	(98)	(95)	(115)	(110)	(35)	(56)	(52)	(68)	(72)	(76)	(32)	(39)	(52)	(42)	(65)	(85)
SEm±	-	0.2	0.4	0.4	0.2	0.3	0.2	0.4	0.1	0.4	0.4	0.2	0.1	0.4	0.3	0.5	0.5	0.5	0.5
CD (P=0.05)	-	0.5	1.2	1.2	0.6	1.0	0.5	1.1	0.3	1.1	1.1	0.7	0.4	1.1	1.0	1.4	1.5	1.4	1.4

trol efficiency and is in line with findings of earlier researchers (Jaya *et al.*, 2011; Singh *et al.*, 2010).

Effect on yield and yield attributes

The effective tillers in various treatments ranged from 296 to 358 in 2019 and 302 to 352 in 2020 (Table 4). Application of florpyrauxifen-benzyl 20 g/L plus cyhalofop butyl 100 g/L at 150 and 180 g a.i./ha recorded statistically at par number of effective tillers (357 and 358 in 2019 and 350 and 352 in 2020, respectively) and grain yield (7.54 t/ha and 7.57 t/ha in 2019 and 7.19 t/ha and 7.33 t/ha in 2020, respectively) and were significantly higher than other herbicidal treatments and unsprayed weedy check. Further, effective tillers and grain yield in 2020 of plots sprayed with penoxsulam + cyhalofop butyl at 135 g a.i./ha (351 and 7.24 t/ha) and bispyribac sodium at 25 g a.i./ha (352 and 7.28 t/ha) were also statistically at par with application of florpyrauxifen-benzyl 20 g/L plus cyhalofop butyl 100 g/L at 150 and 180 g a.i./ha. Thus, weed-free condition in florpyrauxifen-benzyl 20 g/L plus cyhalofop butyl 100 g/L at 150 g a.i./ha could improve the grain yield up to 60.4% in 2019 and 82.0% in 2020 over the unsprayed control plots. This increased yield was due to effective control of different weed flora at critical crop-weed competition. When premix herbicide (florpyrauxifen-benzyl plus cyhalofop butyl) were used, there was no competition between weeds and rice plants, resulting into higher yield (Rizal and Arbiwati, 2024). Weed management practices allows the plant to use available resources effectively by reducing weed density and biomass which resulted in higher grain yield over unsprayed weedy check control and these findings are in line with Kashid (2019) and Choudhary and Dixit (2018).

A negative linear correlateon between weed biomass at 45 DAA with grain yield of DSR production system

Table 4. Effect of different herbicide treatments on effective tillers and grain yield of direct seeded rice during *kharif* 2019 and 2020.

Treatment	Dose (g a.i./ha)	Effective tillers (No./m^2)		Rice grain yield (t/ha)		
		2019	2020	2019	2020	Mean
Florpyrauxifen-benzyl 20 g/L	120	349	333	6.99	6.36	6.68
plus cyhalofop butyl 100 g/L	150	357	350	7.54	7.19	7.36
	180	358	352	7.57	7.33	7.45
Florpyrauxifen-benzyl 2.5 EC	31.25	338	344	6.51	6.78	6.65
Cyhalofop butyl 10 EC	150	324	330	5.21	6.25	5.73
Penoxsulam + cyhalofop butyl 6 OD	135	351	351	7.31	7.24	7.27
Bispyribac sodium 10 SC	25	350	352	7.34	7.28	7.31
Unsprayed control	-	296	302	4.70	3.95	4.32
SEm±	-	1	2	0.06	0.07	-
CD (P=0.05)	-	3	6	0.18	0.22	-

showed that as weed biomass increased, grain yield decreased linearly (Figure 1). This correlation showed that presence of weeds at crop establishment stage adversely affected crop growth by competing for available resources like sunlight, space, nutrients and water. Grain yield showed strong correlation with weed biomass at 45 DAA with coefficient of determination of 0.83, indicating that weed biomass accounted for 83% of variation in grain yield of direct seeded rice (DSR) production system. These findings are in line with Sar *et al.,* (2024). DSR production system is a crucial innovation in securing global food supply amidst environmental challenges. Therefore, weed management is a critical crop protection technology in the success of DSR production system in northwestern India. Moreover, application of pre-emergence herbicide as per the need must be done for better weed management at early crop establishment stage in DSR production system.

Based on the findings of two year present study, it may be concluded that application of premix florpyrauxifen-benzyl 20 g/L plus cyhalofop butyl 100 g/L @ 150 g a.i./ha as post emergence provided effective control of weeds (*Echinochloa crus-galli*, *Cyperus iria* and *Caesulia axillaris*) in DSR production system and resulted in higher rice grain yield.

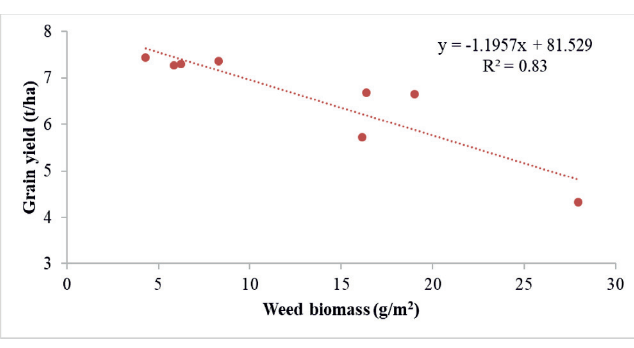

Fig. 1. Relationship of grain yield of DSR production system with respect to weed biomass at 45 DAA

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