



RESEARCH ARTICLE

Efficacy of a new post-emergent herbicide bispyribac-sodium + metsulfuron-methyl + chlorimuron-ethyl (pre-mix) in managing mixed weed flora and improving productivity of transplanted rice

Tarundeep Kaur, Gurinder Singh*, Gurpreet Kaur, Makhan Singh Bhullar, Manpreet Singh, Pervinder Kaur and Simerjeet Kaur

Received: 31 October 2025 | Revised: 24 November 2025 | Accepted: 28 November 2025

Prevention of weed competition during the critical period of rice necessitates the identification of effective and economic options to manage weeds to enhance the rice productivity. Hence, an experiment was conducted to study the efficacy of a new post-emergent herbicide bispyribac-sodium + metsulfuron-methyl + chlorimuron-ethyl (pre-mix) in managing mixed weed flora and improving transplanted rice productivity. Ten treatments were evaluated, during the *kharif* seasons of 2019 and 2020, at the Research Farm of Department of Agronomy, Punjab Agricultural University, Ludhiana, using a randomized complete block design replicated thrice. The post-emergence application (PoE) of bispyribac-sodium 38% plus metsulfuron-methyl 2.5% plus chlorimuron-ethyl 2.5% (bispyribac-sodium + metsulfuron-methyl + chlorimuron-ethyl) (pre-mix) 43 g/ha recorded 42.3% and 19.8%; 63.3% and 56.6% and 75.0% and 83.6% reduction in biomass of grasses, broad-leaved weeds and sedges, at 42 days after application (DAA) during 2019 and 2020, respectively, over control. Bispyribac-sodium + metsulfuron-methyl + chlorimuron-ethyl at 43 g/ha also resulted in 52.8% and 47.0% higher rice grain yield in 2019 and 2020, respectively, over control, there by demonstrating its ability to efficiently control the mixed weed flora and improve the productivity of transplanted rice.

Keywords: Bispyribac-sodium, Chlorimuron-ethyl, Premix herbicide, Metsulfuron-methyl, Transplanted rice, Weed management

INTRODUCTION

Weeds are major contributor to yield loss in rice, along with other biotic and abiotic stresses (Jabran *et al.* 2019). Gharde *et al.* (2018) reported 4420 million USD annual economic losses due to weeds in India. The range of loss in productivity is estimated by the duration and intensity of crop-weed competition (Sardana *et al.* 2017). In Indian rice cultivation, hand weeding twice is commonly practiced, mostly at three and six weeks after transplanting. However, manual weed control is increasingly becoming unaffordable to farmers due to limited labor availability, rising labor costs, the difficulty of distinguishing rice plants from *Echinochloa* spp. during early growth (Rao 2021). To address these challenges, farmers also rely on herbicides for weed management, owing to their effectiveness, affordability and widespread use (Wang *et al.* 2018). Some of the grasses, broad-leaved weeds and sedges are not effectively controlled by application of narrow spectrum herbicides. Premix of herbicides provided broad-spectrum weed control as compared to

application of narrow spectrum herbicide (Choudary and Dixit 2024).

Bispyribac-sodium is a systemic, post-emergent herbicide in the pyrimidinyl oxybenzoic acid group. Bispyribac-sodium translocate within plant tissues and primarily functions by inhibiting acetolactate synthase (ALS), a critical enzyme involved in the biosynthesis of essential branched-chain amino acids necessary for plant growth (Osuna *et al.* 2002). Several studies have confirmed its efficacy in controlling weeds in rice ecosystems, but limited research was done on its performance in combination with other herbicides, particularly in transplanted rice. Another herbicide from the sulfonyleurea class, is metsulfuron-methyl, recognized for its ability to manage over 60 weed species, especially effective against broad-leaved weeds in rice fields (Boutin *et al.* 2012). Similarly, chlorimuron-ethyl also a sulfonyleurea compound, acts by inhibiting ALS, thereby blocking the biosynthesis of vital amino acids such as valine, leucine, and isoleucine, ultimately causing plant death.

The mixture of bispyribac-sodium, metsulfuron-methyl and chlorimuron-ethyl provides an opportunity to effectively manage diverse weed

Department of Agronomy, Punjab Agricultural University, Ludhiana, Punjab 141004, India

* Corresponding author email: gurinderv6@gmail.com

flora during the critical period of crop-weed competition in transplanted rice with its single application after 15-25 days of transplanting (DAT). The pre-mix formulation of this combination is now available. Hence, this study was conducted with an objective to evaluate the efficacy of a new post-emergent herbicide bispyribac- sodium + metsulfuron- methyl + chlorimuron- ethyl (pre-mix) in managing mixed weed flora and improving transplanted rice productivity in Punjab.

MATERIAL AND METHODS

A field experiment was carried out for two consecutive *Kharif* seasons of 2019 and 2020 at the Research Farm of Department of Agronomy, Punjab Agricultural University (PAU), Ludhiana, Punjab, India. The Ludhiana district of Punjab is located at the central plain zone of northwest India (30°54'2" N and 75°48'2" E, 247 m above MSL) and experiences semi-arid, subtropical climate, marked by distinct seasonal variations. The early summer months from March to June are typically hot and dry, followed by a hot and humid monsoon period from July to September. The region then transitions into mild winter during October and November, with the coldest conditions occurring from December to February. Average annual rainfall of Ludhiana district of Punjab is 759 mm, 75-80 percent of which is received during the monsoon period. The soil of experimental field was neutral in pH (7.1-7.4) and electrical conductivity (0.14-0.17 dS/m), low in OC (0.34-0.37%), low in $\text{KMnO}_4\text{-N}$ (233.1-248.2 kg/ha), high in Olsen P (29.8-32.9 kg/ha) and $\text{NH}_4\text{OAc-K}$ (296-317 kg/ha).

Treatments evaluated include: bispyribac-sodium 38% + metsulfuron-methyl 2.5% + chlorimuron-ethyl 2.5% (hereafter: bispyribac-sodium + metsulfuron-methyl + chlorimuron-ethyl) (pre-mix) at 34.4, 43 and 51.6 g/ha; penoxsulam 1.02% + cyhalofop 5.1% OD (hereafter: penoxsulam + cyhalofop) at 135 g/ha; bispyribac-sodium 10% SC (hereafter: bispyribac-sodium) at 25 and 38 g/ha, metsulfuron-methyl 10% + chlorimuron 10% WP (hereafter: metsulfuron + chlorimuron) at 4 and 5 g/ha, unsprayed weedy check (control) and hand weeding twice. All the herbicides were sprayed at 15-25 days after transplanting (DAT) except metsulfuron + chlorimuron, which was applied at 7-10 DAT. A battery-operated knapsack sprayer equipped with flat fan nozzle using 375 liters of water/ha was used for herbicides application at 2-5 leaf stage of weeds under sufficient soil moisture conditions. Hand weeding twice was done at 15 and 30 DAT. The experiment was conducted in a randomized complete block design, and replicated thrice.

Rice cv. *PR 126* was transplanted on June 26th, 2019 and June 25th, 2020, at 20 cm row spacing and 15 cm plant spacing using 20 kg/ha of seed rate for nursery sowing. Each plot was 5.5 m × 2.7 m, forming 14.85 m² area. All recommended cultivation practices were followed to raise the crop, except weed management. The crop was fertilized with 105 kg N, 30 kg P and 30 kg K/ha. Appropriate plant protection practices were implemented to manage insect pests and diseases, ensuring healthy crop growth. The crop was harvested manually on October 24th, 2019 and October 26th, 2020. After harvesting, the crop from each plot was labelled and bundled before threshing. Data on weeds (grasses, broad-leaved weeds and sedge) was recorded species-wise using quadrat (50 cm × 50 cm) randomly placed at two places in each plot at 7, 14, 28 and 42 days after application (DAA) of herbicide. At 42 DAA, weed species, including grasses, broad-leaved weeds, and sedges, were identified, counted, and harvested by cutting at the collar region of the plants. After being collected, each sample was put in brown paper bag and allowed to dry in the sun for 3-5 days. Once surface moisture had evaporated, the bags were transferred to a hot air oven set at 70°C (±2°C) for 72 hours until a constant weight was reached. This final weight was recorded as the weed biomass for each species. For data analysis, weed density (no./m²) and biomass (g/m²) were calculated by averaging the values from two quadrats. Weed control efficiency was calculated using the weed biomass recorded in control plot at 42 DAA, using the formula suggested by Mani *et al.* (1973), as shown below:

$$\text{WCE (\%)} = \frac{\text{WDC} - \text{WDT}}{\text{WDC}} \times 100$$

where,

WDC - Weed biomass in control plot

WDT - Weed biomass in treated plot

The grain yield was recorded at harvest and adjusted at 14% moisture.

Analysis of variance was performed to assess the efficacy of bispyribac-sodium + metsulfuron-methyl + chlorimuron-ethyl and other weed control treatments against complex weed flora in transplanted rice. Statistical analysis of the recorded parameters was conducted separately for each year. IBM SPSS Statistics version 19 was used for analysis of variance with weed control considered as fixed effects. To achieve normal distribution, data related to weed density and biomass were transformed ($\sqrt{x+1}$) before analysis. Significant differences among treatment means were identified using Fisher's Least

Significant Difference (LSD) test at a 5% probability level (Cochran and Cox 1957). Figures of weed control efficiency and correlation between weed biomass at 42 DAA and rice grain yield were worked out by using MS Excel. Principal component analysis (PCA) was performed to assess the relationship between weed biomass at 42 DAA and rice grain yield, using OriginPro software (Origin 2024, version 10.1, OriginLab Corporation, USA).

RESULTS AND DISCUSSION

Weed flora

The predominant weed flora in the study area consisted of grasses, viz. *Echinochloa crus-galli* and *Leptochloa chinensis*; the broad-leaved weed *Ammania baccifera* and sedge *Cyperus iria*.

Weed density

All weed control treatments had significant effect on the weed density at 7, 14, 28 and 42 DAA. Bispyribac-sodium + metsulfuron-methyl + chlorimuron-ethyl 51.6 g/ha provided effective control of *E. crus-galli*, *L. chinensis*, *C. iria* and *A. baccifera* at 7, 14, 28 and 42 DAA. While, penoxsulam + cyhalofop 135 g/ha effectively controlled *E. crus-galli* and *L. chinensis* at 7, 14, 28 and 42 DAA (Tables 1-4). During both years of study, penoxsulam + cyhalofop 135 g/ha and bispyribac-sodium + metsulfuron-methyl + chlorimuron-ethyl 51.6 g/ha recorded at par control of *E. crus-galli* at 7, 14, 28 and 42 DAA except in 2019 at 14 DAA. Bispyribac-sodium + metsulfuron-methyl + chlorimuron-ethyl 51.6 g/ha resulted in 100.0% and 66.7% at 7 DAA, 86.2% and 73.3% at 14 DAA, 85.7% and 62.5% at 28 DAA and 94.4% and

40.0% at 42 DAA control of *E. crus-galli* during 2019 and 2020, respectively. Moreover, bispyribac-sodium 38 g/ha also resulted statistically at par efficacy as penoxsulam + cyhalofop 135 g/ha and bispyribac-sodium + metsulfuron-methyl + chlorimuron-ethyl 51.6 g/ha for controlling *E. crus-galli* at 7 and 14 DAA in 2020 and at 28 and 42 DAA in 2019. On the other hand, during both years, penoxsulam + cyhalofop at 135 g/ha recorded complete (100%) control of *L. chinensis* up to 42 DAA. Metsulfuron + chlorimuron 4 and 5 g/ha and bispyribac-sodium + metsulfuron-methyl + chlorimuron-ethyl 51.6 g/ha provided effective and statistically similar control of *A. baccifera* and *C. iria* at 7 DAA during both years of study and at 14, 28 and 42 DAA in 2019 only. Further, bispyribac-sodium + metsulfuron-methyl + chlorimuron-ethyl 43-51.6 g/ha provided statistically similar control of *A. baccifera* in 2020 and *C. iria* in 2019 at 7, 14, 28 and 42 DAA. However, hand weeding twice resulted in significant control (100%) of all weed flora at 7, 14, 28 and 42 DAA during both years of study (Tables 1-4). The effectiveness of a single herbicide is often limited when used alone. However, a combination of different herbicide chemistries can enhance the spectrum of weed control and provide more comprehensive management without any adverse effects on the crop or environment (Singh et al. 2011). Use of metsulfuron-methyl + chlorimuron-ethyl (pre-mix) was effective in controlling a broad spectrum of weeds (Duary et al. 2016). Bispyribac-sodium alone was not effective against broad-leaved weeds (Nath et al. 2024) and but provided good control of *E. crus-galli*. Thus, the application of pre-mix herbicides could be more effective in lowering the weed competition in rice.

Table 1. Effect of different weed control treatments on weed density (no./m²) at 7 days after herbicide application (DAA) in transplanted rice during Kharif 2019 and 2020

Treatment	Grasses				Broad-leaved weed		Sedge	
	<i>E. crus-galli</i>		<i>L. chinensis</i>		<i>A. baccifera</i>		<i>C. iria</i>	
	2019	2020	2019	2020	2019	2020	2019	2020
Bispyribac-sodium + metsulfuron-methyl + chlorimuron-ethyl 34.3 g/ha	2.99(8)	3.87(14)	2.63(6)	3.19(9)	2.87(7)	2.07(3)	1.96(3)	4.65(21)
Bispyribac-sodium + metsulfuron-methyl + chlorimuron-ethyl 43 g/ha	2.32(5)	3.40(11)	2.37(5)	3.31(10)	2.73(7)	1.24(0.7)	1.24(0.7)	2.20(4)
Bispyribac-sodium + metsulfuron-ethyl + chlorimuron-ethyl 51.6 g/ha	1.00(0)	2.46(5)	2.44(5)	3.40(11)	1.41(1)	1.24(0.7)	1.00(0)	1.55(2)
Penoxsulam + cyhalofop 135 g/ha	1.00(0)	2.63(6)	1.00(0)	1.00(0)	4.35(18)	1.49(1)	1.00(0)	2.99(8)
Bispyribac-sodium 25 g/ha	2.07(3)	3.50(11)	2.51(5)	3.08(9)	3.21(9)	1.66(2)	2.67(2)	2.85(7)
Bispyribac-sodium 38 g/ha	2.20(4)	2.51(5)	2.37(5)	3.31(10)	2.88(7)	1.66(2)	2.07(3)	2.20(4)
Metsulfuron + chlorimuron-ethyl 4 g/ha	3.31(10)	3.85(14)	2.14(4)	3.87(14)	1.24(0.7)	1.00(0)	1.32(2)	1.00(0)
Metsulfuron + chlorimuron-ethyl 5 g/ha	3.46(11)	3.77(13)	2.07(3)	3.60(12)	1.00(0)	1.00(0)	1.49(1)	1.00(0)
Control	4.35(18)	3.95(15)	2.07(3)	3.69(13)	5.19(26)	2.99(8)	4.49(19)	6.75(45)
Hand weeding	1.00(0)	1.00(0)	1.00(0)	1.00(0)	1.00(0)	1.00(0)	1.00(0)	1.00(0)
LSD (p=0.05)	0.54	0.71	0.44	0.53	0.65	0.59	0.76	0.73

*Figures in parentheses are original means. Data were subjected to a square root transformation

Table 2. Effect of different weed control treatments on weed density (no./m²) at 14 DAA in transplanted rice during Kharif 2019 and 2020

Treatment	Grasses				Broad-leaved weed		Sedge	
	<i>E. crus-galli</i>		<i>L. chinensis</i>		<i>A. baccifera</i>		<i>C. iria</i>	
	2019	2020	2019	2020	2019	2020	2019	2020
Bispyribac-sodium + metsulfuron-methyl + chlorimuron-ethyl 34.3 g/ha	3.32(10)	4.01(15)	2.99(8)	3.60(12)	2.99(8)	2.20(4)	1.66(2)	4.12(16)
Bispyribac-sodium + metsulfuron-methyl + chlorimuron-ethyl 43 g/ha	2.99(8)	3.37(11)	2.83(7)	3.60(12)	2.75(7)	1.48(2)	1.24(0.7)	3.41(11)
Bispyribac-sodium + metsulfuron-ethyl + chlorimuron-ethyl 51.6 g/ha	2.20(4)	2.20(4)	3.08(9)	3.68(13)	1.55(2)	1.24(0.7)	1.00(0)	2.51(5)
Penoxsulam + cyhalofop 135 g/ha	1.24(0.7)	2.37(5)	1.00(0)	1.00(0)	3.77(13)	1.66(2)	1.24(0.7)	2.63(6)
Bispyribac-sodium 25 g/ha	1.90(3)	3.50(11)	3.31(10)	3.60(12)	2.63(6)	2.20(4)	2.51(5)	2.07(3)
Bispyribac-sodium 38 g/ha	1.24(0.7)	2.88(7)	3.08(9)	3.60(12)	1.41(1)	1.41(1)	2.07(3)	1.66(2)
Metsulfuron + chlorimuron-ethyl 4 g/ha	4.03(15)	3.41(11)	3.20(9)	3.60(12)	1.00(0)	1.00(0)	1.55(2)	1.00(0)
Metsulfuron + chlorimuron-ethyl 5 g/ha	3.60(12)	3.85(14)	3.21(9)	3.51(11)	1.00(0)	1.00(0)	1.24(0.7)	1.00(0)
Control	5.45(29)	3.92(15)	3.69(13)	3.96(15)	3.69(13)	3.69(13)	5.13(25)	4.93(23)
Hand weeding	1.00(0)	1.00(0)	1.00(0)	1.00(0)	1.00(0)	1.00(0)	1.00(0)	1.00(0)
LSD (p=0.05)	0.56	0.73	0.66	0.42	0.74	0.64	0.77	0.52

*Figures in parentheses are original means. Data were subjected to a square root transformation; DAA = days after herbicide application

Table 3. Effect of different weed control treatments on weed density (no./m²) at 28 DAA in transplanted rice during Kharif 2019 and 2020

Treatment	Grasses				Broad-leaved weed		Sedge	
	<i>E. crus-galli</i>		<i>L. chinensis</i>		<i>A. baccifera</i>		<i>C. iria</i>	
	2019	2020	2019	2020	2019	2020	2019	2020
Bispyribac-sodium + metsulfuron-methyl + chlorimuron-ethyl 34.3 g/ha	3.19(9)	4.34(18)	3.31(10)	3.69(13)	3.41(11)	2.32(5)	1.00(0)	4.24(17)
Bispyribac-sodium + metsulfuron-methyl + chlorimuron-ethyl 43 g/ha	3.21(9)	3.49(11)	3.41(11)	3.60(12)	2.88(7)	1.49(1)	1.00(0)	2.43(5)
Bispyribac-sodium + metsulfuron-ethyl + chlorimuron-ethyl 51.6 g/ha	1.73(2)	2.63(6)	3.11(9)	3.67(13)	1.67(3)	1.24(0.7)	1.00(0)	1.90(3)
Penoxsulam + cyhalofop 135 g/ha	1.24(0.7)	2.49(5)	1.00(0)	1.00(0)	2.99(8)	1.41(1)	1.66(2)	2.20(4)
Bispyribac-sodium 25 g/ha	1.49(1)	3.41(11)	3.31(10)	4.12(16)	1.80(3)	1.49(1)	1.49(1)	4.19(17)
Bispyribac-sodium 38 g/ha	1.24(0.7)	3.21(9)	3.60(12)	3.95(15)	1.66(2)	1.24(0.7)	1.49(1)	1.90(3)
Metsulfuron + chlorimuron-ethyl 4 g/ha	3.50(11)	3.68(13)	3.31(10)	3.69(13)	1.49(1)	1.00(0)	1.24(0.7)	1.00(0)
Metsulfuron + chlorimuron-ethyl 5 g/ha	3.87(14)	3.85(14)	3.60(12)	3.69(13)	1.00(0)	1.00(0)	1.00(0)	1.00(0)
Control	3.87(14)	4.10(16)	3.96(15)	3.87(14)	3.60(12)	3.89(14)	5.25(27)	4.98(24)
Hand weeding	1.00(0)	1.00(0)	1.00(0)	1.00(0)	1.00(0)	1.00(0)	1.00(0)	1.00(0)
LSD (p=0.05)	0.54	0.68	0.41	0.50	0.80	0.64	0.53	0.62

*Figures in parentheses are original means. Data were subjected to square root transformation; DAA = days after herbicide application

Table 4. Effect of different weed control treatments on weed density (no./m²) at 42 DAA in transplanted rice during Kharif 2019 and 2020

Treatment	Grasses				Broad-leaved weed		Sedge	
	<i>E. crus-galli</i>		<i>L. chinensis</i>		<i>A. baccifera</i>		<i>C. iria</i>	
	2019	2020	2019	2020	2019	2020	2019	2020
Bispyribac-sodium + metsulfuron-methyl + chlorimuron-ethyl 34.3 g/ha	3.02(8)	4.43(19)	3.95(15)	3.87(14)	3.60(12)	2.04(3)	1.66(2)	4.04(15)
Bispyribac-sodium + metsulfuron-methyl + chlorimuron-ethyl 43 g/ha	3.01(8)	3.69(13)	3.41(11)	3.87(14)	3.11(9)	1.49(1)	1.24(0.7)	2.49(5)
Bispyribac-sodium + metsulfuron-ethyl + chlorimuron-ethyl 51.6 g/ha	1.49(1)	3.21(9)	3.60(12)	3.51(11)	1.55(2)	1.24(0.7)	1.00(0)	1.66(2)
Penoxsulam + cyhalofop 135 g/ha	1.24(0.7)	2.75(7)	1.00(0)	1.00(0)	2.88(7)	2.20(4)	1.49(1)	2.07(3)
Bispyribac-sodium 25 g/ha	2.37(5)	3.85(14)	3.40(11)	3.61(12)	1.49(1)	2.37(5)	1.49(1)	1.90(3)
Bispyribac-sodium 38 g/ha	1.24(0.7)	3.60(12)	4.12(16)	3.32(10)	1.66(2)	1.41(1)	1.24(0.7)	1.49(1)
Metsulfuron + chlorimuron-ethyl 4 g/ha	3.87(14)	3.95(15)	4.12(16)	3.87(14)	1.79(3)	1.24(0.7)	1.24(0.7)	1.00(0)
Metsulfuron + chlorimuron-ethyl 5 g/ha	4.12(16)	3.20(9)	3.40(11)	3.78(13)	1.00(0)	1.00(0)	1.00(0)	1.00(0)
Control	4.34(18)	4.03(15)	3.48(11)	3.85(14)	4.12(16)	3.85(14)	5.19(26)	4.02(15)
Hand weeding	1.00(0)	1.00(0)	1.00(0)	1.00(0)	1.00(0)	1.00(0)	1.00(0)	1.00(0)
LSD (p=0.05)	0.67	0.51	0.46	0.38	0.83	0.72	0.59	0.57

*Figures in parentheses are original means. Data were subjected to square root transformation; DAA = days after herbicide application

Weed biomass and weed control efficiency

Hand weeding twice resulted in complete control of all weeds up to 42 DAA. All herbicidal treatments recorded significantly lower grasses, broad-leaved weeds and sedge biomass and higher weed control efficiency than control in both years. At 42 DAA, bispyribac-sodium + metsulfuron-methyl + chlorimuron-ethyl 51.6 g/ha recorded *E. crus-galli* biomass reduction of 84.1% in 2019 and 82.1% in 2020, over control plot and was statistically similar with penoxsulam + cyhalofop 135 g/ha. Bispyribac-sodium + metsulfuron-methyl + chlorimuron-ethyl 51.6 g/ha provided higher weed control efficiency in case of *E. crus-galli* (84.1% in 2019 and 82.1% in 2020) and *A. baccifera* (100% in 2019 and 88.5% in 2020) at 42 DAA. However, during both years of study, penoxsulam + cyhalofop 135 g/ha recorded complete (100%) reduction of biomass and 100% weed control efficiency of *L. chinensis* and was proved superior to all other herbicidal treatments. During both years of study, metsulfuron + chlorimuron at 4 and 5 g/ha recorded statistically

similar and lower weed biomass and cent percent (100%) weed control efficiency of *A. baccifera* and *C. iria* except *A. baccifera* in 2019 (Table 5, Figure 1). Bispyribac-sodium is an acetolactate synthase inhibiting herbicide is widely utilized in rice cultivation to manage some weeds (López-Piñeiro *et al.* 2022). Another herbicide, metsulfuron-methyl, is a low-use-rate sulfonylurea herbicide widely used for post-emergence broad-leaved weed control in rice fields due to its strong inhibitory effect on plant growth (Boutin *et al.* 2012). As other sulfonylurea herbicides, chlorimuron-ethyl acts by inhibiting acetolactate synthase (ALS), an essential enzyme involved in the synthesis of branched-chain amino acids. Chlorimuron-ethyl is effective for providing control for wide range of weeds at low application rates, exhibits good crop selectivity, and has low acute and chronic toxicity while maintaining high biological efficiency. The adoption of newly formulated pre-mix post-emergence herbicides has shown greater efficacy in controlling weed flora, leading to improved crop productivity (Babaei *et al.* 2022).

Table 5. Effect of different weed control treatments on weed biomass (g/m²) at 42 DAA, grain yield (t/ha) of transplanted rice and benefit cost ratio (B:C) during Kharif 2019 and 2020

Treatment	Grasses				Broad-leaved weed		Sedge		Rice grain yield (t/ha)		B:C	
	<i>E. crus-galli</i>		<i>L. chinensis</i>		<i>A. baccifera</i>		<i>C. iria</i>					
	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020	2019	2020
Bispyribac-sodium + metsulfuron-methyl + chlorimuron-ethyl 34.3 g/ha	6.13(37)	7.44(55)	7.04(49)	7.77(59)	5.67(31)	3.90(14)	5.19(26)	4.84(22)	6.06	6.95	2.80	3.48
Bispyribac-sodium + metsulfuron-methyl + chlorimuron-ethyl 43 g/ha	3.87(14)	5.45(29)	7.14(50)	8.05(64)	3.51(11)	3.33(10)	3.69(13)	3.27(10)	7.18	7.19	3.45	3.59
Bispyribac-sodium + metsulfuron-ethyl + chlorimuron-ethyl 51.6 g/ha	3.31(10)	3.29(10)	6.55(42)	7.46(55)	3.60(12)	2.44(6)	1.00(0)	2.86(7)	7.38	7.39	3.53	3.66
Penoxsulam + cyhalofop 135 g/ha	3.41(11)	3.24(10)	1.00(0)	1.00(0)	3.95(15)	3.91(14)	2.64(7)	4.16(16)	7.40	7.21	3.37	3.38
Bispyribac-sodium 25 g/ha	6.00(35)	5.73(32)	6.90(47)	7.25(52)	5.03(24)	3.79(13)	3.87(14)	5.00(24)	6.99	6.98	3.43	3.55
Bispyribac-sodium 38 g/ha	3.74(13)	5.37(28)	7.37(53)	8.14(65)	2.73(8)	3.56(12)	3.46(11)	3.71(13)	7.14	6.93	3.44	3.44
Metsulfuron + chlorimuron-ethyl 4 g/ha	6.55(42)	7.30(53)	7.32(53)	7.52(56)	3.31(11)	1.00(0)	1.67(3)	1.00(0)	6.48	6.26	3.22	3.19
Metsulfuron + chlorimuron-ethyl 5 g/ha	7.09(49)	7.55(56)	6.98(48)	7.53(56)	1.00(0)	1.00(0)	1.00(0)	1.00(0)	6.58	6.34	3.27	3.24
Control	7.20(63)	7.55(56)	6.98(48)	7.83(60)	5.57(30)	4.88(23)	7.27(52)	7.85(61)	4.70	4.89	2.08	2.30
Hand weeding	1.00(0)	1.00(0)	1.00(0)	1.00(0)	1.00(0)	1.00(0)	1.00(0)	1.00(0)	7.33	7.21	3.31	3.37
LSD (p=0.05)	2.26	0.57	0.38	0.27	1.10	0.74	0.97	0.41	0.41	0.43	-	-

*Figures in parentheses are original means. Data were subjected to a square root transformation; DAA = days after herbicide application

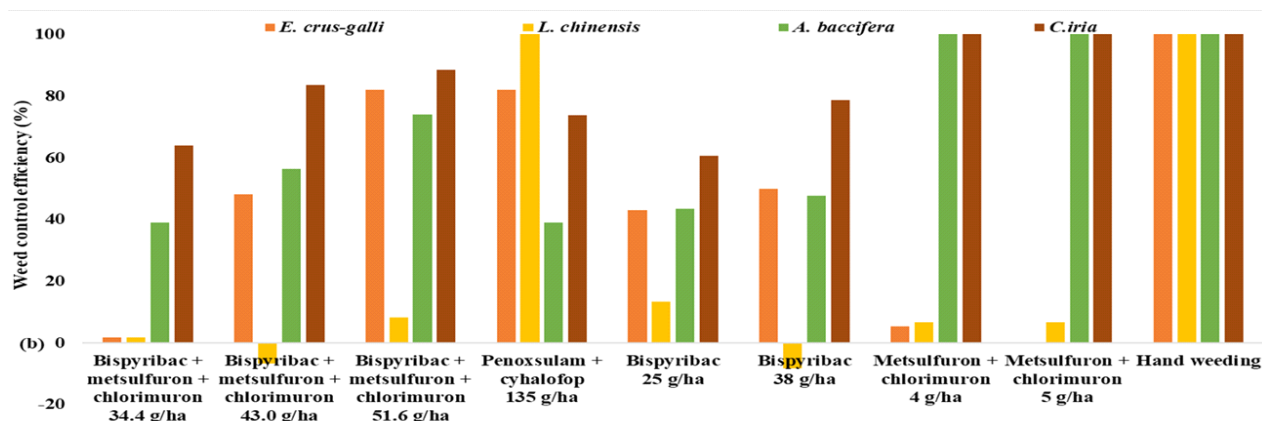


Figure 1. Weed control efficiency of grasses, broad-leaved weeds and sedges at 42 days after herbicide application (DAA) in (a) 2019 and (b) 2020

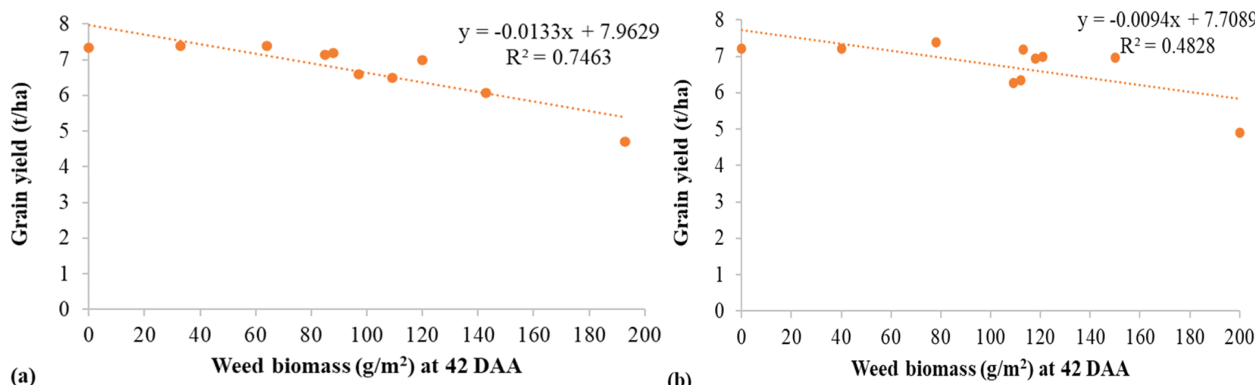


Figure 2. Relationship of grain yield of rice with weed biomass at 42 days after herbicide application (DAA) in (a) 2019 and (b) 2020

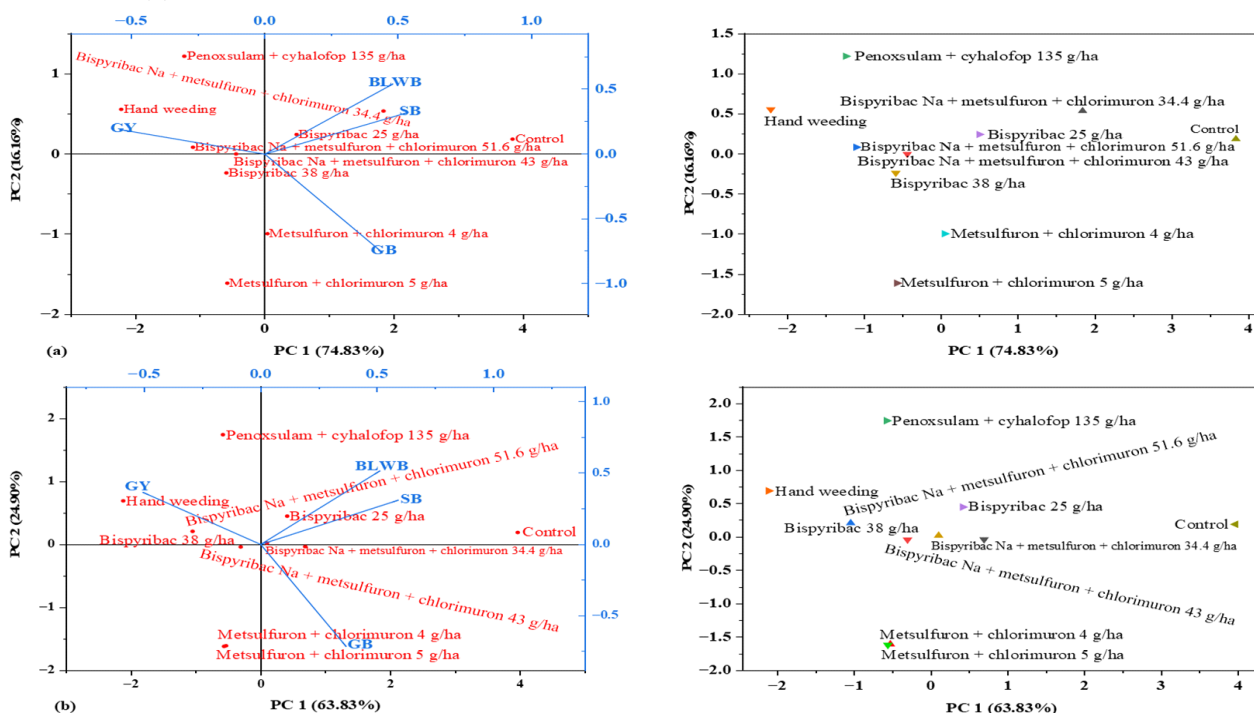


Figure 3. Principal component analysis between weed biomass at 42 days after herbicide application (DAA) and grain yield of rice in (a) 2019 and (b) 2020; GY: grain yield (t/ha), GB: grasses biomass (g/m²), BLWB: broad-leaved weed biomass (g/m²), SB: sedge biomass (g/m²)

Rice grain yield and benefit cost ratio (B:C)

Different herbicidal treatments had significant impact on the grain yield of rice (Table 5). The bispyribac-sodium + metsulfuron-methyl + chlorimuron-ethyl (pre-mix) 51.6 g/ha PoE recorded at par grain yield with its lower dose *i.e.*, 43 g/ha, penoxsulam + cyhalofop 135 g/ha, bispyribac-sodium 25 g/ha and hand weeding. Moreover, in 2019, bispyribac-sodium 38 g/ha also resulted in grain yield of rice statistically at par with bispyribac-sodium + metsulfuron-methyl + chlorimuron-ethyl (pre-mix) 43 g/ha. Furthermore, weed-free conditions under bispyribac sodium + metsulfuron methyl + chlorimuron ethyl (pre-mix) 43 g/ha led to significant increase in grain yield up to 52.8% in 2019 and 47.0% in 2020, respectively over control.

Moreover, bispyribac-sodium + metsulfuron-methyl + chlorimuron-ethyl (pre-mix) 51.6 g/ha recorded higher B:C (3.53 in 2019 and 3.66 in 2020) followed by its lower dose *i.e.*, 43 g/ha (3.45 in 2019 and 3.59 in 2020). During the critical growth period, weeds compete with rice for essential resources such as space, water, light and nutrients (Kaur *et al.* 2025a) and inadequate weed management has been linked to reduced crop yields (Boydston *et al.* 2017). The tested newly formulated post-emergence pre-mix herbicide achieved more effective weed control, reducing crop-weed competition, and enhancing crop productivity. Acetolactate synthase inhibiting herbicides are widely utilized in rice crop to manage weeds and their use often contributes to increased grain yields (López-Piñeiro *et al.* 2022).

A strong negative linear correlation was observed between rice grain yield and weed biomass at 42 DAA, indicating that grain yield declined as weed biomass increased (**Figure 2**). This relationship suggests that weed presence during the peak vegetative stage significantly hinders rice crop growth by competing for essential resources such as nutrients, sunlight and water. The coefficient of determination (R^2) values: 0.7463 in 2019 and 0.4828 in 2020, further support this trend, showing that weed biomass accounted for approximately 75% and 48% of the variability in rice grain yield during 2019 and 2020, respectively.

Principal component analysis (PCA) between weed biomass at 42 DAA and grain yield of rice

Principal component analysis (PCA) revealed that the first (PC1) and second principal components (PC2) together explained 91.0% of the total variation in 2019 and 88.7% in 2020 for weed biomass (grasses, broad-leaved weed, and sedge at 42 DAA) and rice grain yield across various weed control treatments (**Figure 3**). The blue arrows in the biplot depict variables such as grain yield and the biomass of different weed groups. The direction of each arrow reflects its contribution to the principal components, with longer arrows indicating greater influence. The angle between arrows shows the degree of correlation, where smaller angles indicate a positive relationship, while arrows pointing in opposite directions suggest a negative correlation. The biomass of grasses, broad-leaved weed and sedge at 42 DAA displayed long arrows-oriented opposite to that of grain yield, indicating a strong negative correlation between weed biomass and rice grain yield.

Conclusion

It can be concluded that bispyribac-sodium + metsulfuron-methyl + chlorimuron-ethyl 43-51.6 g/ha (pre-mix) PoE provided effective and economical control of grasses (*Echinochloa crus-galli* and *Leptochloa chinensis*), broad-leaved weed (*Ammania baccifera*) and the sedge (*Cyperus iria*) during the critical period of crop-weed competition in transplanted rice resulting in higher benefit: cost ratio than all other treatments.

ACKNOWLEDGEMENT

The authors thank PI Industries Ltd. for providing samples of bispyribac-sodium 38% plus metsulfuron-methyl 2.5% plus chlorimuron-ethyl 2.5%.

REFERENCES

Babaei S, Lahooni S, Mousavi SK, Tahmasebi I, Sabeti P and Abdulahi, A. 2022. Efficiency of herbicides for weed control in chickpea and effect of their residues on wheat growth. *Agronomía Colombiana* 40(2): 249–257.

- Boutin C, Aya KL, Carpenter D, Thomas PJ and Rowland O. 2012. Phytotoxicity testing for herbicide regulation: shortcomings in relation to biodiversity and ecosystem services in agrarian systems. *Science of The Total Environment* 415: 79–92.
- Boydston RA, Nelson H and Chaves-Cordoba B. 2018. Tolerance of chickpeas to postemergence broadleaf herbicides. *Weed Technology* 32(2): 190-194.
- Cochran WG and Cox GM. 1957. *Experimental Design*. 2nd Edition, John Wiley and Sons, New York, 615 p
- Duary B, Kumar M, Teja KC and Dash S. 2016. Weed management in dry direct seeded rice through integrated approaches In: Proceedings of 4th International Agronomy Congress, New Delhi, India during Nov. 22-26, 2016 Extended Summaries Vol. 1, 277–278.
- Gharde Y, Singh PK, Dubey RP and Gupta PK. 2018. Assessment of yield and economic losses in agriculture due to weeds in India. *Crop Protection* 107: 12–18.
- Jabran K, Uludag A and Chauhan BS. 2019. Sustainable weed control in rice. In: Korres NE, Burgos NR, Duke SO editors. Vol. 10, *Weed control: sustainability, hazards and risks in cropping systems worldwide*, Boca Raton, FL, CRC Press, Taylor & Francis Group. p. 276–287.
- Kaur T, Kaur S, Singh G, Singh M, Singh J, Kaur P, Kaur P and Bhullar MS. 2025a. Weed control in direct seeded rice with ready mix of penoxsulam + pendimethalin. *Indian Journal of Weed Science* 57(2): 155–159.
- López-Piñero A, Martín-Franco C, Terrón-Sánchez J, Vicente LA, Fernández-Rodríguez D, Albarrán Á, Nunes JMR and Peña D. 2022. Environmental fate and efficiency of bispyribac sodium in rice soils under conventional and alternative production systems affected by fresh and aged biochar amendment. *Science of the Total Environment* 847: 157651.
- Mani VS, Malla ML, Gautam KC and Das B. 1973. Weed killing chemical in potato cultivation. *PANS* 23(8): 17–18.
- Nath CP, Kumar N, Hazra KK, Dutta A, Praharaj CS, Singh R, Singh SS, Dubey RP, Sen S, Dixit GP and Kumar D. 2024. Five years of conservation tillage and weed management in a rice-chickpea rotation of northern Gangetic Plains of India: Weed growth, yield benefits and economic profitability. *Soil and Tillage Research* 244: 106226.
- Origin. 2024. OriginPro 2024, 10.1. OriginLab Corporation
- Osuna MD, Vidotto F, Fischer AJ, Bayer DE, De Prado R and Ferrero A. 2002. Cross-resistance to bispyribac-sodium and bensulfuron-methyl in *Echinochloa phyllopogon* and *Cyperus difformis*. *Pesticide Biochemistry and Physiology* 73: 9–17.
- Rao AN. 2021. *Echinochloa colona* and *Echinochloa crus-galli*. Chapter 10. Pp. 197- 239. In: (Chauhan BS, ed), *Biology and Management of Problematic Crop Weed Species*. Elsevier Inc.
- Sardana V, Mahajan G, Jabran K and Chauhan BS. 2017. Role of competition in managing weeds: An introduction to the special issue. *Crop Protection* 95: 1–7.
- Singh S, Punia SS, Yadav A and Hooda VS. 2011. Evaluation of carfentrazone-ethyl+ metsulfuron-methyl against broadleaf weeds of wheat. *Indian Journal of Weed Science* 43(1&2): 12–22.
- Wang H, Liu W, Zhao K, Yu H, Zhang J and Wang J. 2018. Evaluation of weed control efficacy and crop safety of the new HPPD-inhibiting herbicide-QYR301. *Scientific Reports* 8(1): 7910.