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Efficacy assessment of Bispyribac Sodium 9.5% + Penoxsulam 7.8% SC for weed management in winter rice

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ABSTRACT

A field experiment was conducted in the New Alluvial Zone of West Bengal (22°93′ N, 88°53′ E and 9.75m MSL) during the kharif seasons of 2018 and 2019 to manage weeds in transplanted winter rice at the Instructional Farm, Jaguli, Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal, using Randomized Block Design with eight treatment combinations replicated thrice. The results demonstrated that bispyribac sodium 9.5% + penoxsulam 7.8% SC @ 25.65 + 21.06 g a.i. ha^{-1} and bispyribac sodium 9.5% + penoxsulam 7.8% SC @ 23.75 + 19.5 g a.i. ha^{-1} achieved significantly higher grain and straw yield among chemical treatments which were statistically similar with twice hand weeding treatment. Bispyribac sodium 9.5% + penoxsulam 7.8% SC @ 25.65 + 21.06 g a.i. ha^{-1} generated higher net return and benefit-cost ratio. Although both Bispyribac sodium 9.5% + Penoxsulam 7.8% SC @ 23.75 + 19.5 g a.i. ha^{-1} and Bispyribac sodium 9.5% + Penoxsulam 7.8% SC @ 25.65 + 21.06 g a.i. ha^{-1} exhibited improved weed control efficiency, net return, and benefit-cost ratio as compared to twice hand weeding treatment, Bispyribac sodium 9.5% + Penoxsulam 7.8% SC @ 23.75 + 19.5 g a.i. ha^{-1} might be adopted ensuring better environmental safety.

Keywords*:* Benefit-cost ratio, Bispyribac sodium 9.5% + Penoxsulam 7.8% SC, winter rice, Weed control efficiency and yield

Rice plays a vital role in ensuring food security and facilitating subsistence development, as it serves as the main dietary staple for over 60% of the global population. However, weeds are recognized as a primary impediment to achieving high rice productivity due to their diverse detrimental impacts. Weeds lead to a yield decrease of approximately 15-20% in anaerobic transplanted rice, 30-35% in anaerobic direct seeded puddled rice, and more than 50% in case of aerobic direct seeded upland rice. In direct-seeded rice, weed competition is critical within 15-30 days of germination, and within 30-60 days for transplanted rice. Manual weeding, common among Indian farmers, is labour-intensive, slow, and costly, requiring 250-780 man-days per hectare. Labour shortages due to industrialization, better education, and urban migration, along with inconsistent field conditions from rainy seasons, make manual weeding challenging. Herbicides, therefore, offer an effective early-stage weed management solution. Herbicides not only save precious time and resources but also enable the coverage of larger areas within a shorter timeframe, facilitating timely weed management. Currently, several newly developed chemicals such as bispyribac sodium, butachlor, pendimethalin, propanil, pyrazosulfuron-ethyl, benthiocarb oxadiazone, anilofos, and others are accessible for managing weeds in transplanted rice. While eco-friendly weed control is prioritized, farmers increasingly prefer chemical methods due to rising labour costs.

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Effective weed control during the critical crop-weed rivalry phase, using physical techniques or herbicides, offers an economical alternative, especially with labour shortages or adverse weather. Proper herbicide use requires understanding their effectiveness, selectivity, and application rates. This knowledge is crucial to mitigate potential environmental and health risks. Based on these ideas, the present experiment was designed with the objective to evaluate the efficacy of herbicides in a single and mixed form with proper effective dose to control different types of weeds in transplanted rice.

MATERIALS AND METHODS

An experiment was carried out at the Jaguli Instructional Farm of Bidhan Chandra Krishi Viswavidyalaya, Nadia, West Bengal. The experimental site was geographically located at 22°93' N latitude, 88°53' E longitude and 9.75m MSL in the New Alluvial Zone. The experiment was carried in the *kharif* season (known as Aman) of 2018 and 2019 with eight treatments replicated thrice in Randomized Block Design, *viz.*,T_1: Bispyribac sodium 9.5% + Penoxsulam 7.8% SC @ 19 +15.6 g a.i. ha^{-1}, T_2: Bispyribac sodium 9.5% + Penoxsulam 7.8% SC @ 23.75 + 19.5 g a.i. ha^{-1}, T_3: Bispyribac sodium 9.5% + Penoxsulam 7.8% SC @ 25.65 + 21.06 g a.i. ha^{-1}, T_4: Bispyribac sodium 10% SC @ 25 g a.i. ha^{-1}, T_5: Penoxsulam 21.7% SC @ 22.5 g a.i. ha^{-1}, T_6: Penoxsulam 1.02% SC + Cyhalofop-butyl 5.1% @ 135 g a.i. ha^{-1}, T_7: Hand weeding (twice) at 20 and 40 days after transplanting (DAT), and T_8: weedy check. Rice variety IET 4786 (known as 'Satabdi') was transplanted in 24 plots (5 m × 4 m) at a spacing of 20cm × 15cm and fertilizers were administered in accordance with the recommended amounts of nitrogen, phosphorus, and potassium (N: P_2O_5: K_2O @ 60:30:30 kg ha^{-1}). Nitrogenous fertilizer was applied in three separate splits *viz.*, 1/4 N as basal, 1/2 N at 20 DAT and rest 1/4 N at 40 DAT, whereas P and K were applied as basal in full doses. Herbicide was uniformly applied to all treatment plots using a post-emergence approach specifically at 20 days after transplanting (DAT), aligning with the 3 - 4 leaf stage of the weeds. For the weed-free plot, manual hand weeding was performed at 20 and 40 days after transplanting (DAT). Weed density and the dry weight of weeds were recorded at 45 days after treatment (DAT) as per standard methods and weed control efficiency was computed respectively. The growth parameters including plant height, leaf area index (LAI), dry matter accumulation (DMA), crop growth rate (CGR), yield and yield attributes of rice were recorded and simultaneously economics was worked out. Pooled analysis over 2018-2019 was carried out by SPSS 17.0.2. Weed control efficiency was estimated by a simple mathematical formula as:

$$WCE(\%) = \frac{DWC - DWT}{DWT} \times 100$$

Where,
WCE = Weed control efficiency, DWC = Dry weight of weed in un-weeded plot, DWT = Dry weight of weed in control plot

RESULTS AND DISCUSSION

Impact of weed control measures on density, dry weight and control efficiency of weeds

It was demonstrated in table - 1 that at 45 days after planting (DAT), T_7 showed the minimum grassy weed population (1.55 m^{-2}), while the weedy check (T_8) recorded the maximum (6.68 m^{-2}). Sedge population decreased in T_7 due to the second hand weeding; while in other treatments, sedge density increased compared to previous observations. T_8 had the highest increasing rate of weed population and the minimum population was recorded in hand-weeded plots (1.07m^{-2}). At 45 DAT, T_7 recorded the lowest broadleaf weed population, and increasing rates were highest in T_8. According to Yadav *et al*. (2009), the utilization of bispyribac-sodium and penoxsulam resulted in decreased weed density in transplanted rice fields. Similar findings were documented by Tripathy *et al*. (2018), who observed comparable efficacy in managing grasses, sedges and broadleaved weeds in rice fields.

As shown in table - 1, the hand weeding treatment performed twice (T_7) exhibited the lowest weed dry weight (0.62 g m^{-2}) at 45 DAT, while the highest dry weight (7.55 g m^{-2}) was observed in T_8 (weedy check). Among the herbicidal treatments, T_3 recorded lowest (2.82 g m^{-2}) weed dry weight, which was statistically similar to T_1 (3.38 g m^{-2}), T_2 (2.98 g m^{-2}) and T_6 (3.49 g m^{-2}). At 45DAT, a decline in dry weight was observed for the hand weeding treatment, while among the herbicidal treatments, the lowest value was recorded in T_3 (2.62 g m^{-2}) preceded by T_2 (2.92 g m^{-2}). Lower weed dry weight of 0.65 g m^{-2} was observed in T_7, while the maximum dry weight of 10.01 g m^{-2} was recorded in T_8. At 45 DAT, broad leaf weed population was reduced in case of T_7 resulting in subsequent reduction in dry weight and among the combined herbicidal treatments, T_3 (2.12 g m^{-2}) and T_2 (2.28 g m^{-2}) recorded better performance; however, effect of T_3 was statistically at par with T_2. These results align with the findings of Nalini *et al*. (2012).

At 45 DAT, the highest weed control efficiency was observed in treatment T_7 (Table 1), recording a rate of 90.34%. Among the herbicidal treatments, T_3 exhibited the highest value of

69.36% followed by T_2 at 67.98%, while the minimum value was recorded in T_4 at 52.05%. These outcomes correspond to the conclusions presented in the study of Nalini *et al*. (2012).

Table 1: Effect of weed control measures on weed density, dry weight of weeds, and weed control efficiency (Pooled)

Treatments	Weed density at 45 DAT (number m^{-2})			Dry weight of weeds at 45 DAT (g m^{-2})			Weed control efficiency at 45 DAT (%)
	Grass	Sedge	Broad Leaf	Grass	Sedge	Broad Leaf	
T_1 - Bispyribac sodium 9.5% + Penoxsulam 7.8% SC @ 19 +15.6 g a.i. ha^{-1}	3.82 *(14.13)	2.68 (6.70)	2.22 (4.45)	3.38	3.37	2.71	63.00
T_2 - Bispyribac sodium 9.5% + Penoxsulam 7.8% SC @ 23.75 + 19.5 g a.i. ha^{-1}	3.42 (11.22	2.15 (4.16)	2.12 (4.00)	2.98	2.92	2.28	67.98
T_3 - Bispyribac sodium 9.5% + Penoxsulam 7.8% SC @ 25.65 + 21.06 g a.i. ha^{-1}	3.05 (8.82)	1.90 (3.13)	1.92 (3.2)	2.82	2.62	2.12	69.36
T_4 - Bispyribac sodium 10% SC @ 25 g a.i. ha^{-1}	4.31 (18.14)	3.22 (9.92)	3.08 (9.01)	4.18	4.79	3.84	52.05
T_5 - Penoxsulam 21.7% SC @ 22.5 g a.i. ha^{-1}	3.87 (14.51)	3.38 (10.95)	3.05 (8.86)	3.64	3.97	3.62	56.03
T_6 - Penoxsulam 1.02% SC + Cyhalofop-butyl 5.1% @ 135 g a.i. ha^{-1}	3.85 (14.36)	3.14 (9.36)	2.77 (7.21)	3.49	3.72	3.30	59.07
T_7 - Hand weeding (twice) at 20 and 40 days after transplanting (DAT)	1.55 (1.93)	1.07 (0.66)	0.70 (0)	0.62	0.65	0.80	90.34
T_8 - weedy check	6.68 (44.22)	4.51 (19.85)	3.75 (13.62)	7.55	10.01	7.98	0.00
SEm (±)	**0.12**	**0.10**	**0.17**	**0.26**	**0.23**	**0.20**	**2.29**
LSD (0.05)	**0.34**	**0.29**	**0.50**	**0.77**	**0.66**	**0.58**	**6.76**

*Note: *Data subjected to square root transformation (√X+0.5), Values in parentheses are original*

Impact of weed control measures on the growth parameters of rice

Various weed control treatments had a notable influence on plant height, leaf area index (LAI), dry matter accumulation (DMA), and crop growth rate (CGR) at 90 days after transplanting (Table 2). Based on analysis, T_7 exhibited the highest plant height (86.93cm); whereas among herbicidal treatments, T_3 showed the tallest plant height (83.80 cm) which was statistically comparable to that of T_2 (81.12 cm). In case of dry matter accumulation among herbicidal treatment at 90 DAT, T_3 also accumulated the highest dry matter (768.39 g m^{-2}), subsequently by T_2 (733.13g m^{-2}). This might be due to the lower weed infestation in T_3 compared to that in T_2, allowing efficient resource use by the crop. The highest LAI was recorded in T_7 (3.55) treatment and the lowest in T_8 (2.67) at 90DAT; whereas among the herbicidal treatments, the highest LAI was observed in T_3 (3.46). Highest crop growth rate during 75-90 DAT was noticed under T_3 (9.15g$m^{-2}day^{-1}$) followed by T_2, T_1, T_5, T_7, T_6, T_4, T_8. Higher weed infestation leads to higher weed biomass, resulting in lower LAI, DMA, and CGR values for crops as documented in the study conducted by Ashraf *et al*. (2014).

Table 2: Effect of different weed control treatments on rice growth parameters (Pooled)

Treatments	Growth Parameters			
	Plant height (cm)	DMA (g m^{-2})	LAI	CGR (g m^{-2} day^{-1})
	90 DAT	90 DAT	90 DAT	75-90 DAT
T_1 - Bispyribac sodium 9.5% + Penoxsulam 7.8% SC @ 19 +15.6 g a.i. ha^{-1}	78.81	682.10	3.11	8.76
T_2 - Bispyribac sodium 9.5% + Penoxsulam 7.8% SC @ 23.75 + 19.5 g a.i. ha^{-1}	81.12	733.13	3.41	8.95
T_3 - Bispyribac sodium 9.5% + Penoxsulam 7.8% SC @ 25.65 + 21.06 g a.i. ha^{-1}	83.80	768.39	3.46	9.15
T_4 - Bispyribac sodium 10% SC @ 25 g a.i. ha^{-1}	76.52	625.03	2.90	7.24
T_5 - Penoxsulam 21.7% SC @ 22.5 g a.i. ha^{-1}	77.68	630.16	2.87	8.74
T_6 - Penoxsulam 1.02% SC + Cyhalofop-butyl 5.1% @ 135 g a.i. ha^{-1}	76.70	641.43	3.06	8.28
T_7 - Hand weeding (twice) at 20 and 40 days after transplanting (DAT)	86.93	816.43	3.55	8.48
T_8 - weedy check	74.66	510.56	2.67	4.85
SEm (±)	**0.83**	**12.78**	**0.10**	**0.47**
LSD (0.05)	**2.43**	**0.28**	0.28	1.44

Impact of weed control measures on rice yield attributes, yield and economics

The yield and yield-related characteristics of rice were notably affected by the weed management practices, except for test weight, as shown in Table 3. Hand weeding (twice) at 20 and 40 days after transplanting (DAT) resulted in the highest number of grains per panicle (138.82) due to reduced crop-weed competition and better nutrient absorption by the crop. Among the herbicidal treatments, Bispyribac sodium 9.5% + Penoxsulam 7.8% SC @ 25.65 + 21.06 g a.i. ha^{-1} (T_3) demonstrated the highest value (126.80), followed by Bispyribac sodium 9.5% + Penoxsulam 7.8% SC @ 23.75 + 19.5 g a.i. ha^{-1} (T_2) and Bispyribac sodium 9.5% + Penoxsulam 7.8% SC @ 19 +15.6 g a.i. ha^{-1}(T_1) without having significant difference amongst them. Test weight did not significantly differ among treatments, as it is a genetic trait. Hand weeding (twice) at 20 and 40 days after transplanting (DAT) had the highest test weight (20.04 g), while weedy check had the lowest (19.28 g). Similar observations regarding improved yield attributes in transplanted rice were reported by Raj *et al*. (2016) and Menon *et al*. (2017) when bispyribac-sodium and penoxsulam were applied. Among the different treatments, T_7 achieved the highest grain yield of 3.61 t ha^{-1}, whereas the lowest yield of 2.42 t ha^{-1} was observed in T_8. T_3 exhibited highest grain yield of 3.47 t ha^{-1} among the herbicidal treatments, followed by T_2 and T_1 with yield 3.29 and 3.07 t/ha respectively. Weed is a major limiting factor of yield loss, as stated by Dass et *al.* (2017). T_7 resulted in the highest straw yield of 4.27 t ha^{-1}, which was statistically at par with the straw yield obtained after chemical treatments T_1, T_2, and T_3. Conversely, in treatment T_8, the straw yield observed was the lowest measuring 3.30 tons per hectare, which was statistically similar to T_4 and T_5. Teja *et al.* (2015) reported similar findings in accordance with these results. The application of penoxsulam 24% SC at a rate of 20.0-22.5 g ha^{-1} resulted in improved yield attributes and overall yield of transplanted rice by effectively controlling the weed complex. These findings align with the results obtained by Khare *et al*. (2014) and Sasna (2014). The harvest index of rice ranged from 42.33% to 45.86%. The highest harvest index was observed in T_7, which involved hand weeding; while the minimum value was noted in T_8. Among the herbicidal treatments, T_3, consisting of bispyribac sodium 9.5% at a rate of 25.65 g a.i. ha^{-1} and penoxsulam 7.8% at a rate of 21.06 g a.i. ha^{-1}, exhibited the highest harvest index, followed by the T_2.

Table 3: Effect of different weed control treatments on rice yield attributes, yield and economics (Pooled)

Treatments	Yield attributes and yield					Economics	
	Number of grains panicle^{-1}	1000 seed weight (g)	Grain yield (t ha^{-1})	Straw yield (t ha^{-1})	Harvest index (%)	Net return (Rs.)	B:C
T_1 - Bispyribac sodium 9.5% + Penoxsulam 7.8% SC @ 19 +15.6 g a.i. ha^{-1}	113.83	19.52	3.07	3.81	44.62	23940	1.67
T_2 - Bispyribac sodium 9.5% + Penoxsulam 7.8% SC @ 23.75 + 19.5 g a.i. ha^{-1}	125.45	19.67	3.29	4.03	44.97	27792	1.78
T_3 - Bispyribac sodium 9.5% + Penoxsulam 7.8% SC @ 25.65 + 21.06 g a.i. ha^{-1}	126.80	19.75	3.47	4.20	45.27	31068	1.86
T_4 - Bispyribac sodium 10% SC @ 25 g a.i. ha^{-1}	110.63	19.48	2.76	3.63	43.19	17952	1.50
T_5 - Penoxsulam 21.7% SC @ 22.5 g a.i. ha^{-1}	107.70	19.45	2.81	3.64	43.59	20429	1.60
T_6 - Penoxsulam 1.02% SC + Cyhalofop-butyl 5.1% @ 135 g a.i. ha^{-1}	104.90	19.56	2.87	3.66	43.98	20960	1.60
T_7 - Hand weeding (twice) at 20 and 40 days after transplanting (DAT)	138.82	20.04	3.61	4.27	45.86	25387	1.57
T_8 - weedy check	99.46	19.28	2.42	3.30	42.33	14107	1.42
SEm (±)	**5.34**	**0.32**	**0.12**	**0.18**	-	-	-
LSD (0.05)	**15.63**	**NS**	**0.34**	**0.52**	-	-	-

The net return and B: C ratio of rice were significantly impacted by the weed control treatments, as indicated in Table 3. T_3 resulted in the highest net return of Rs. 31,068 ha^{-1}, subsequently of T_2; whereas, T_8 (weedy check) recorded the lowest net return of Rs. 14,107 ha^{-1}.The treatment involving manual weeding was carried out twice at 20 and 40DAT. T_7, had a lower net return than T_3 and T_2 (Rs. 25387 ha^{-1}). Similar type of result had been opined by Shelar (2014). Among the herbicidal treatments, T_3 noted the maximum benefit-to-cost (B:C) ratio of 1.86, followed by T_2 with a ratio of 1.78. In case of T_7, the B:C ratio value was 1.57. Kumar *et al*. (2015) also reported similar results.

CONCLUSION

Combined use of Bispyribac sodium 9.5% + Penoxsulam 7.8% SC @ (25.65 + 21.06) g a.i ha^{-1} (T_3) and Bispyribac sodium 9.5% + Penoxsulam 7.8 % SC @ (23.75 + 19.5) g a.i ha^{-1} (T_2) attained satisfactory performance in terms of better weed control efficiency, net return and B:C ratio than twice hand weeding treatment. Between T_2 and T_3 treatments, in terms of environmental safety, it is recommended to consider that T_2 treatment, which involves the application of Bispyribac sodium 9.5% + Penoxsulam 7.8% SC @ (23.75 + 19.5) g a.i. ha^{-1}, for effective weed control and better economic returns in transplanted rice.

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