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Effect of integrated weed management on yield and economics of rice (*Oryza sativa* L.) in *Vertisols* of Chhattisgarh

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Abstract
The present investigation aimed to evaluate the “Effect of integrated weed management on yield and economics of rice (*Oryza sativa* L.) in *Vertisols* of Chhattisgarh” during the *kharif* season of 2022 at the Instructional Farm, Alesur, DKS, College of Agriculture and Research Station, Bhatapara (C.G.). The study was conducted using a Randomized Block Design (R.B.D.) with 10 treatments, each replicated 03 times. Notably, the treatment labeled as "Weed-free check" (W2) demonstrated superior results in terms of higher panicle count, longer panicle length, increased grain yield and better test weight, showcasing its effectiveness in weed control and its subsequent positive impact on rice growth. Moreover, the integration of pre-emergence herbicide with hand weeding (W4) showed promising outcomes for weed management and yield improvement. Economic parameters, including the cost of cultivation, gross income, net income and benefit-cost ratios, also highlighted the economic benefits of effective weed management. Treatment W2 (Weed-free check) led to the highest gross returns and net returns, emphasizing the importance of weed control for economic viability. In conclusion, the study indicated that treatment W2 (Weed-free check) and W4 (Pyrazosulfuron Ethyl 10% WP @ 20 g a.i. ha^{-1} at 3 DAT (PRE) + Hand weeding at 20 DAT) showed superior results in terms of, plant growth and yield and yield attributes. These findings emphasize the importance of effective weed management practices to achieve better economic outcomes in rice cultivation in *Vertisols* of Chhattisgarh.

Keywords: Rice, yield, pre-emergence, post-emergence, pyrazosulfuron ethyl, *Oryza sativa*, hand weeding and economic

Introduction
Rice (*Oryza sativa* L.) holds a central role as the primary staple crop in Asia and various tropical and subtropical regions worldwide, as highlighted by Anonymous in 1997 [1]. Research conducted by Rahman and Masood in 2012 underscores that approximately two-thirds of the population in Asian countries rely on rice to meet their daily calorie needs. The remarkable increase in rice production, which has multiplied six-fold since 1950, can be attributed to advancements in the development of high-yield rice varieties, the expansion of irrigation resources, and the heightened application of fertilizers, as documented by both Anonymous (1997) [1] and Naganjali *et al.*, (2023) [15].

Globally, rice was demand is expected to the increase by 25.00% from the year 2001 to 2026 to meet the requirement of increasing world population (Rosegrant *et al.*, 2002) [17]. Globally, total rice area is about 164.62 M ha, production is 504.71 Mt with productivity of 3.1 t ha^{-1} (Anon., 2021) [2].

In India, factors such as an increase in the MSP of rice and its adaptability to various biotic and abiotic stresses have made rice a preferable crop for farmers, especially those who are marginal farmers is well-suited to India's diverse growing conditions and provides an economically viable option for small-scale and resource- poor growers due to supportive national pricing policies. In Indian subcontinent, rice is grown with an area of 45.07 M ha and 122.27 Mt of production and 2713 kg ha^{-1} productivity in the year 2020-21 (Anonymous, 2021a) [3]. Chhattisgarh, situated in central-eastern India, is often referred to as the "Rice bowl of India" due to its significant role in rice production. In 2021, the state cultivated approximately 3.70 million hectares of rice, resulting in a substantial harvest of 4.89 million tonnes. What's particularly impressive is the high productivity rate of 3002 kilograms per hectare, emphasizing the region's agricultural prowess.

This remarkable performance underscores Chhattisgarh's pivotal contribution to India's rice production, making it a vital component of the country's food security and agricultural landscape (Anonymous, 2021b) [4].

Weed is a major yield limit factors in rice cultivation and production (Bastiaans *et al.*, 1997) [5]. Weeds in wet-direct seeded rice emerging along with the crops and competing for nutrients, light, moisture and space. Generally, wet-direct seeded rice fields are infested by sedges, grasses and broad leaf weeds. Most dominant weed species of transplanted rice was found *Echinochloa colona*, *Commelina communis* and *Caesulia axillaris* (Dixit and Bhan, 2003) [8]. Weed competition in rice is very serious during early growth stages (15-30 DAS), causing yield reduction data range from 40-100% (Choubey *et al*., 2001) [6]. Weed management is a substantial challenge in wet and dry direct-seeded rice, especially during the initial growth stages. Inadequate weed control can result in substantial yield reduction, as highlighted by Kotresh *et al.* (2022) [10]. To optimize productivity and minimize yield losses, it is imperative to implement timely and efficient weed control measures in direct-seeded rice systems. Addressing weeds effectively during this crucial period is essential for achieving the desired crop yields and maintaining the overall success of rice cultivation.

Materials and Methods

A field experiment was carried out on rice during *kharif* season, 2022 at Instructional Farm, Alesur, DKSCARS, Bhatapara, (C.G.).

This experiment focused on the cultivation of CG Zinc Rice 2, a rice variety, during the *Kharif* season of 2022. It employed a Randomized Block Design and initiated transplanting on July 31, 2022. The gross plot size was 8m × 4m, totaling 32 square meters, while the net plot size, the actual experimental area was 7m × 3m, equivalent to 21 square meters. The study included 10 different treatments with each treatment replicated three times, resulting in a total of 30 plots. To maintain separation between replications, a gap of 1 meter was maintained. This experimental setup aimed to explore various aspects of rice growth and performance under different conditions and treatments.

Results and Discussion

Among the data on effect of integrated weed management practices on number of panicles hill^{-1}, panicle length, no. of grains panicle^{-1} and test weight (g) have been presented in Table 1.

The result showed that significantly highest no. of panicles hill^{-1} (21.47) and longest panicle length (26.41 cm) was found in the treatment W2 (Weed-free check), however it was significant at par with the treatments W4, W5, W6, W7, W8 and W10 in both parameters. Maximum no. of grains per panicle (182.67) was also found in the treatment W2 (Weed free check) which was at par with W4, W6 and W7. Higher test weight (20.00 g) was found in the treatment W2 (Weed free check), which was followed by W4 (19.96), which was at par with W3, W5, W6, W7, W8 and W10 respectively. Lowest no. of panicles hill^{-1}, panicle length, no. of grains panicle^{-1} was found in the treatment W1 (Weedy check) compared with treatment W2 (Weed-free check).

The integration of Pre remaining and post-emergence herbicides along with the hand weeding was the most effective weed management practice for enhancing yield attributes and eventually rice yield compared to sole herbicide applications or mechanical weeding.

The result finding due to combination of herbicide with hand weeding (W4) can effectively control weeds and improve rice yield and yield components. The other herbicide treatments (W3, W5, W7 and W8) also showed promise but were not as effective as the combination treatment or the weed-free check (W2). Cultural practices such as cono weeding can be a viable alternative to herbicides in small holder farming systems. The findings of the study provide evidence that effective weed management practices are essential for achieving high rice yields. The combination of herbicide with hand weeding was found to be the most effective method, while multiple passes of cono weeder also showed promising result. The study highlights the importance of timely and appropriate weed management activity in rice cultivation to minimize yield losses due to weed competition. The results observed and present study are supported by the works of Singh and Singh (2010) [18], Mahmud *et al*., (2016) [12], Suryakala *et al*., (2019) [20].

Among the data in Table 2 show the effects of different integrated weed management practices on grain yield (kg ha^{-1}) and straw yield (kg ha^{-1}).

The results showed that grain yield and straw yield in kg/ha varied under different integrated weed management practices. The treatment W2 (weed-free check) produced significantly higher grain yield (5028 kg/ha) and straw yield (8531 kg/ha) compared to the other treatments. This was likely due to the absence of weed competition throughout the crop growth period. The next best treatment was W4 [Pyrazosulfuron Ethyl 10% WP @ 20 g active ingredient/ha at 3 days after transplanting (PRE) + Hand weeding at 20 DAT]. In contrast, treatment W1 (Weedy check) exhibited the lowest grain yield and straw yield relative to the other treatments, presumably because weeds were allowed to compete with the crop throughout its growth cycle.

Due to the IWM practices led to highest grain yield due to reduced weed competition, optimal crop establishment and minimized weed infestation. Weed control measurement limited weed dry matter-accumulation and enhanced nutrient in uptake, promoting crop growth and health. Timely weed management prevented prolonged weed competition, reducing crop losses. Improved crop stand density, better access to resources and minimized weed interference contributed to increased grain yield. Additionally, healthier crops showed resilience against environmental stresses, further enhancing productivity. Integrated weed management ensured a more uniform plant stand and reduced weed infestation, providing long-term benefits for sustained high grain yield. These outcomes are consistent with findings of Hossain and Malik (2017) [9] and Lhungdim *et al*., (2019) [11].

The results demonstrated that integrating pre-emergence herbicides with post- emergence herbicides and hand weeding was the most effective approach for increasing yields. Treatment W4 [Pyrazosulfuron Ethyl 10% WP applied at 20 g active ingredient/ha at 3 days after transplanting (PRE) followed by hand weeding at 20 DAT] produced the highest grain yield (4422 kg/ha) and straw yield (8413 kg/ha), comparable to treatment W2 (weed-free check). Treatment W6 [Bispyribac Sodium 10% W/V SC applied at 20 g active ingredient/ha at 20 days after transplanting (post-emergence) followed by one hand weeding at 30 DAT] also exhibited improved grain and straw yields. Treatments W3, W6, W7

and W8 resulted in greater grain and straw yields than the weedy check (W1), but lower than the weed-free check. Treatment W2 (weed-free check) consistently demonstrated the highest grain and straw yields among all treatments, reflecting the benefit of complete weed control. The higher yields in treatments W4 and W6, as well as the weed-free check (W2), can be attributed to effective weed control measures. Both treatment W4 and treatment W6 combined pre- emergence herbicides with post-emergence herbicides and hand weeding. This dual approach significantly minimized weed competition, providing the rice crop with better access to essential resources, including nutrients, water, and sunlight. The result was improved grain and straw yields, with treatment W4 producing the highest yields, comparable to the weed-free check (W2). These findings underscore the importance of comprehensive weed management strategies in optimizing rice production and minimizing yield losses.

Straw yield was also positively influenced by integrated weed management practices under treatment W2 (weed-free check) and W4 [Pyrazosulfuron Ethyl 10% WP @ 20 g a.i. ha^{-1} at 3 DAT (PRE) + Hand weeding at 20 DAT] by effectively controlling weeds, the weed competition of the nutrients, water and sunlight was minimized, allowing the crop to utilize resources more efficiently. As a result, the crops exhibited healthier vegetative growth and greater tillering capacity, leading to higher straw biomass production. Additionally, reduced weed pressure prevented lodging, ensuring that the crop stood upright and thus avoided potential yield losses caused by lodging-related issues. The integration of various weed management techniques contributed to maintaining an optimal crop stand, which directly impacted the straw yield positively. This increase in straw yield not only provided valuable crop residues for soil health and organic matter, but it also enhanced overall crop productivity and agricultural sustainability. The finding of present study is in accordance by Mahmud *et al*., (2016) [12] and Meera *et al*., (2016) [14].

Due to the integrated weed management practices had varying effects on grain yield and straw yield treatments involving hand weeding and specific herbicide applications showed improved yields compared to the weedy check but were still lower than the weed-free check. The weed-free check (W2) treatment consistently exhibited the highest yields, emphasizing the importance of effective weed management strategies for enhancing crop productivity. Also, similar results were reported by Sunil *et al.,* (2010) [19], Dolie *et al*., (2023) [7] and Mahmud *et al*., (2016) [12].

The data pertaining to effect of IWM practices on cost of cultivation (₹ ha^{-1}), gross returns (₹ ha^{-1}) and net returns (₹ ha^{-1}) and benefit cost ratio (B:C ratio) have been presented in Table 3.

The data revealed that the treatment W2 (Weed-free check) had the highest gross returns of ₹ 1,34,226 ha^{-1}, resulting in a net return of ₹ 83,059 ha^{-1} followed by W4 [Pyrazosulfuron Ethyl 10% WP @ 20 g a.i. ha^{-1} at 3 DAT (PRE) + Hand weeding at 20 DAT]. Highest B:C ratio obtained under W4 (1.80) followed by W6 (1.70), W2 (1.62), W8 (1.55) and W7 (1.54). Treatment W1 (Weedy check) had the lowest gross returns of ₹ 58,262 ha^{-1}, resulting in a net return of ₹ 21,945 ha^{-1} and a B:C ratio of 0.60. The results indicate that effective weed management practices can significantly increase the gross returns, net returns and B:C ratio.

The cono weeder treatments, cono weeder once at 15 DAT (W9) and cono weeder twice at 10 and 20 DAT (W10), had lower gross returns than the herbicide- based treatments. However, they still resulted in positive net returns and B:C ratios, indicating that cono weeding can be a viable option for weed management in some situations.

In the results of this study indicate that integrated weed management practices that include a combination of herbicides and hand weeding or cono weeding can increase the gross returns, net returns and B:C ratio of rice cultivation. However, the choice of weed management practice should be based on the specific weed flora and the economic feasibility of each practice.

Due to the integration of selective herbicide with hand weeding effectively controlled weeds, reduced competition and improved rice yield. This, along with the relatively lower costs of weeding, translated to significantly higher gross returns, net returns and B:C ratios compared to the weedy check and sole herbicide applications which involved higher costs but were less effective in improving yield. Therefore, integrating herbicide with hand weeding proved to be the most economically viable weed management option. The results obtained in the present study are supported by the works of Mukherjee (2019) [13].

Table 1: Number of panicles hill^{-1}, Panicle length (cm), Number of grains panicle^{-1}, Test weight (g) Grain yield (kg ha^{-1}) and straw yield (kg ha^{-1}), Cost of cultivation (₹ ha^{-1}), Gross returns (₹ ha^{-1}), Net returns (₹ ha^{-1}) and Benefit cost ratio (B:C Ratio) as influenced by integrated weed management practices

Tr. No.	Treatment Details	Number of panicles hill^{-1}	Panicle length (cm)	Number of grains panicle^{-1}	Test weight (g)	Grain Yield (kg ha^{-1})	Straw Yield (kg ha^{-1})	Cost of cultivation (₹ ha^{-1})	Gross returns (₹ ha^{-1})	Net returns (₹ ha^{-1})	B:C Ratio
W1	Weedy check	14.10	19.84	124.70	17.33	2142	4703	36317	58262	21945	0.60
W2	Weed-free check	21.47	26.41	182.67	20.00	5028	8531	51167	134226	83059	1.62
W3	Pyrazosulfuron Ethyl 10% WP @ 20 g a.i. ha^{-1} at 3 DAT (PRE)	17.94	22.10	153.79	18.91	3245	7162	39992	88281	48289	1.21
W4	Pyrazosulfuron Ethyl 10% WP @ 20 g a.i. ha^{-1} at 3 DAT (PRE) + Hand weeding at 20 DAT	21.11	25.97	178.67	19.96	4422	8413	42467	118951	76484	1.80
W5	Bispyribac Sodium 10% W/V SC @ 20 g a.i. ha^{-1} at 20 DAT (PoE)	18.59	23.24	163.24	18.97	3628	6820	40442	97514	57072	1.41
W6	Bispyribac Sodium 10% W/V SC @ 20 g a.i. ha^{-1} at 20 DAT (PoE) + One hand weeding at 30 DAT	20.59	25.13	174.79	19.65	4325	7831	42924	115944	73020	1.70

W7	Pyrazosulfuron Ethyl 10% WP @ 20 g a.i. ha^{-1} at 3 DAT (PRE) + Bispyribac Sodium 10% W/V SC @ 20 g a.i. ha^{-1} at 20 DAT (PoE)	19.93	24.48	170.67	19.64	4182	7626	44117	112169	68052	1.54
W8	+ Almix (Metsulfuron Methyl 10% + Chlorimuron Ethyl 10% WP) @ 4 g a.i. ha^{-1} at 20 DAT (PoE)	19.24	23.98	167.49	19.33	3875	7468	40892	104338	63446	1.55
W9	Cono weeder once at 15 DAT	16.84	21.13	144.73	18.90	3088	6751	38627	83945	45318	1.17
W10	Cono weeder twice at 10 and 20 DAT	18.12	22.91	158.41	18.93	3412	7219	40937.00	92516	51579	1.26
	S.Em±	1.18	1.24	4.98	0.36	118	373	-	2823	2823	0.069
	CD (0.05)	3.51	3.69	14.82	1.09	350	1109	-	8388	8388	0.21

Conclusion

In conclusion, the post-harvest observations, including parameters such as the post-harvest observations *viz.* no. of panicles hill^{-1}, number of grains panicle^{-1}, panicle length (cm), test weight (g), grain yield (kg ha^{-1}) included straw yield (kg ha^{-1}) were found significantly maximum in treatment weed-free check (W2).

The economic parameters like cost of cultivation of rice (₹ ha^{-1}), gross returns (₹ ha^{-1}) of rice and net returns (₹ ha^{-1}) of rice were found highest in treatment weed- free check (W2) and benefit cost ratio (B:C Ratio) was higher in treatment (W4) pyrazosulfuron ethyl 10% WP @ 20 g a.i. ha^{-1} at 3 DAT (PRE) + hand weeding at 20 DAT.

The result was concluded that present study that "Effect of integrated weed management on growth and yield of rice (*Oryza sativa* L.) in *Vertisols* of Chhattisgarh" from the overall performance, observation and association study of yield and yield attributes and economics parameters stand could be the better performance in first in best position treatment is weed-free check (W2). Similar result was found in treatment (W4) pyrazosulfuron ethyl 10% WP @ 20 g a.i. ha^{-1} at 3 DAT (PRE) + hand weeding at 20 DAT and (W6) bispyribac sodium 10% W/V SC @ 20 g a.i. ha^{-1} at 20 DAT (PoE) + one hand weeding at 30 DAT. Therefore, the study concludes that integrated weed management strategies significantly data influenced rice growth and yield in *Vertisols* of Chhattisgarh, with weed-free check (W2) and certain herbicide-based treatments leading to enhanced performance across various parameters.

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