Type of Article-Original Research Article

The Impact of Integrated Weed Management Practices on Nutrient Uptake in Rice (*Oryza sativa* L.)

Abstract

The study investigated the impact of integrated weed management practices on nutrient uptake in rice (*Oryza sativa* L.) and weeds at 90 days after transplanting (DAT) over the 2022 and 2023 growing seasons at the Crop Research Centre (CRC) farm of Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut. Various weed control strategies, including the application of pre-emergence and post-emergence herbicides combined with manual weeding, were evaluated for their effectiveness in enhancing the uptake of essential nutrients such as nitrogen (N), phosphorus (P), and potassium (K) by rice, while also reducing nutrient loss to weeds. Among the strategies tested, the combination of Pyrazosulfuron at 150 g active ingredient per hectare (a.i. ha^{-1}) as a pre-emergence herbicide and Penoxsulam at 22 g a.i. ha^{-1} as a post-emergence herbicide, supplemented with one manual weeding at 40 DAT, proved to be the most effective. This approach resulted in the highest nutrient uptake by rice and the lowest nutrient uptake by weeds. In this treatment, nitrogen uptake in the rice grains reached 62.7 kg per hectare in 2022 and 67.4 kg per hectare in 2023, significantly outperforming other treatments. The weed-free treatment, which involved complete weed eradication, also demonstrated high nutrient absorption, highlighting the importance of thorough weed control for optimal rice growth. Conversely, the untreated weedy check, where no weed control was implemented, led to the highest nutrient uptake by weeds, severely limiting the availability of nutrients for the rice crop. Manual weeding alone, without the use of herbicides, showed moderate effectiveness but was less efficient compared to the integrated approach combining herbicides and hand weeding.

Keywords: *Nutrient uptake, Pyrazosulfuron, Penoxsulam, Nutrient Uptake, Rice*

1. Introduction

Rice (*Oryza sativa* L.) is universally recognized as the most crucial staple food crop, feeding nearly 60% of the global population. Its significance in India is profound, where rice constitutes approximately 43% of the total food grain production and 46% of the total cereal production, underscoring its central role in ensuring food security across the nation. Rice cultivation not only dominates the agricultural landscape but also provides essential income and employment for over 50 million households, particularly within rural communities [1]. The global demand for rice continues to grow, with China and India consuming large portions of Asia's rice production-one-third in China and one-fifth in India. This has led to a cultivation area of 158 million hectares worldwide, with annual production exceeding 527 million tonnes. As the second-largest producer and consumer of rice after China, India alone cultivates rice on 43.57 million hectares, producing 104.32 million tonnes annually, and achieving a productivity rate of 2.98 tonnes per hectare.

Despite its agricultural importance, rice production faces several significant challenges in India. Declining natural resources, labor shortages, and escalating weed infestations threaten the sustainability and productivity of rice cultivation [2]. Weeds, in particular, represent a formidable obstacle to rice farming. They compete with rice plants for critical resources such as nutrients, light, and space, especially during the early growth stages. If left unchecked, weed growth can result in yield losses ranging from 12% to 51%, depending on the extent of infestation and the management methods employed. In transplanted rice systems, the problem is exacerbated as weeds often emerge simultaneously with rice seedlings, intensifying competition for nutrients and other growth factors. Weeds alone account for 45% of total annual agricultural production losses in India, surpassing other threats such as insect pests and diseases [3]. Their aggressive growth and adaptability allow them to overrun the crop environment, leading to significant reductions in rice yield. The critical period for rice-weed competition occurs during the vegetative phase, making effective weed control during this period essential for maximizing rice productivity.Traditional methods of weed control, such as hand weeding, while effective, are labor-intensive and increasingly impractical for large-scale farming. In response, chemical weed control, particularly the use of herbicides, has gained traction as a more practical and cost-effective solution, particularly in transplanted rice systems. However, while herbicides are efficient, the continuous use of the same chemical agents has caused shifts in weed flora and contributed to the development of herbicide-resistant weed species. This has prompted the need for more sustainable solutions, leading to the increasing recognition of integrated weed management (IWM) strategies. IWM employs a combination of cultural, mechanical, and chemical methods to achieve more sustainable weed control. By reducing reliance on herbicides and promoting eco-friendly practices, IWM aims to maintain long-term productivity while safeguarding environmental health [4].

In India, labor shortages, rising herbicide costs, and the need for more efficient weed management systems have driven the adoption of IWM in rice cultivation. Weed control is critical not only for improving crop yields but also for enhancing nutrient uptake by rice plants. Weeds, through their competition with rice for essential nutrients like nitrogen, phosphorus, and potassium, can severely restrict the availability of these key elements, all of which are vital for the proper growth and development of rice [5]. Thus, effective weed management practices, incorporating herbicides and timely mechanical interventions, are essential to mitigate these losses and ensure that rice plants have access to sufficient nutrients. This context highlights the importance of understanding the impact of IWM practices on nutrient uptake in rice, which is critical for optimizing rice productivity and ensuring food security in India and other rice-dependent regions.The present study aims to evaluate the effectiveness of integrated weed management practices in transplanted rice ecosystems, particularly their impact on nutrient uptake by both rice and weeds. By investigating various weed control methods, including chemical and mechanical interventions, this research seeks to identify sustainable and cost-effective strategies that not only enhance rice yield but also minimize nutrient loss to weeds. The findings of this study will contribute to ongoing efforts to improve rice production systems, particularly in India, and will support broader initiatives aimed at achieving food self-sufficiency and meeting future food demands in rice-dependent regions globally.

2. Material and Method

The field experiment was conducted over two consecutive years, 2022 and 2023, at the Crop Research Centre (CRC) farm of Sardar Vallabhbhai Patel University of Agriculture and Technology, Meerut, located in the Indo-Gangetic plains of Western Uttar Pradesh, India. The geographical coordinates of the study area are 29°40′ N latitude and 77°42′ E longitude, with an elevation of 237 meters above mean sea level. The site experiences a semi-arid and sub-tropical climate, characterized by extreme temperature fluctuations, with hot summers and cold winters. During both years of the study, the temperature patterns showed a gradual decrease from the third week of November, reaching the lowest in December and January, followed by a steady increase from early February. The weekly mean maximum temperature during the crop-growing period ranged from 37.6°C to 15.4°C, and the mean minimum temperature ranged from 5.9°C to 20.7°C, ensuring stable climatic conditions for the experiment.

The experiment was laid out in a Randomized Block Design (RBD) with 12 treatment combinations and three replications. The treatments were designed to evaluate different weed management practices, including a weedy check (no weed control), weed-free conditions (complete removal of weeds), farmer's practices (one hand weeding at 40 days after transplanting [DAT]), and the application of herbicides such as Pyrazosulfuron 150 g a.i. ha^{-1} (pre-emergence), Bispyribac Sodium 25 g a.i. ha^{-1} (post-emergence at 15 DAT), Ethoxy sulfuron 20 g a.i. ha^{-1} (pre-emergence), and Penoxsulam 22 g a.i. ha^{-1} (post-emergence). The herbicides were applied either alone or in combination with one hand weeding at 40 DAT. The plot sizes were maintained with a gross plot size of 5 x 4 m^2 and a net plot size of 4 x 3 m^2, with a spacing of 20 x 10 cm between the rice plants. The rice variety PB-1637 was used for planting in both 2022 and 2023.Nutrient uptake (N, P, and K) by the rice crop was measured at harvest in both grain and straw. Weed nutrient uptake (N, P, and K) was also assessed at 90 DAT to evaluate the competition between weeds and rice for nutrients.Statistical analysis was performed using the analysis of variance (ANOVA) method in SPSS software. Treatment means were compared using the least significant difference (LSD) test at a 5% probability level to assess the significance of the results [6]. The comparison of the treatments across both years allowed for a comprehensive understanding of the efficacy of the weed management practices in improving rice nutrient uptake and yield while minimizing competition from weeds.

3. Result and Discussion

Nutrient Uptakeof Weeds

The data presented in (Table 1) clearly shows the significant impact of different weed management practices on nutrient uptake (kg ha^{-1}) by weeds at 90 days after transplanting (DAT) during the 2022 and 2023 growing seasons. The weedy check treatment (T1: No weed control) exhibited the highest nutrient uptake, with nitrogen levels reaching 29.3 kg ha^{-1} in 2022 and 36.8 kg ha^{-1} in 2023, phosphorus uptake at 8.0 kg ha^{-1} and 10.4 kg ha^{-1} in the respective years, and potassium uptake at 30.5 kg ha^{-1} in 2022 and 37.9 kg ha^{-1} in 2023. This indicates the significant nutrient depletion caused by uncontrolled weeds, emphasizing their aggressive competition for resources, which reduces nutrient availability for rice. In stark contrast, the weed-free treatment (T2: Complete weed removal) recorded zero nutrient uptake in both years, illustrating the efficacy of thorough weed control in preventing nutrient loss to weeds.Farmer's practices involving one hand weeding at 40 DAT (T3) moderately reduced nutrient uptake, with nitrogen uptake of 13.1 kg ha^{-1} in 2022 and 16.5 kg ha^{-1} in 2023, along with reduced phosphorus and potassium uptake, indicating that manual weeding effectively controls weed growth but does not fully eliminate competition. The application of

Pyrazosulfuron 150 g a.i. ha^{-1} as a pre-emergence herbicide (T4) showed a further reduction in nutrient uptake, with nitrogen values dropping to 8.4 kg ha^{-1} in 2022 and 10.6 kg ha^{-1} in 2023. Combining Pyrazosulfuron with one hand weeding at 40 DAT (T5) resulted in even lower nutrient uptake, with nitrogen levels at 7.4 kg ha^{-1} in 2022 and 9.3 kg ha^{-1} in 2023. This combination highlights the added benefit of integrated methods, where both chemical and manual controls suppress weed competition more effectively than using a single method.Post-emergence application of Bispyribac Sodium 25 g a.i. ha^{-1} at 15 DAT (T6) also led to significant reductions in nutrient uptake, though slightly less effective than pre-emergence applications. Nutrient uptake further decreased when Bispyribac Sodium was combined with one hand weeding at 40 DAT (T7), with nitrogen uptake of 7.9 kg ha^{-1} in 2022 and 10.0 kg ha^{-1} in 2023. Similar trends were observed with Ethoxy sulfuron 20 g a.i. ha^{-1} (T8), and its combination with hand weeding (T9), as well as with Penoxsulam 22 g a.i. ha^{-1} (T10), and its combination with hand weeding (T11), where nutrient uptake consistently dropped, demonstrating the synergistic effect of integrating chemical and manual weed control practices.The most effective treatment in reducing nutrient uptake was the combination of Pyrazosulfuron 150 g a.i. ha^{-1} (pre-emergence) and Penoxsulam 22 g a.i. ha^{-1} (post-emergence) with one hand weeding at 40 DAT (T12), which recorded the lowest nutrient uptake across both years, with nitrogen levels at 6.0 kg ha^{-1} in 2022 and 7.6 kg ha^{-1} in 2023. This treatment exemplifies the effectiveness of integrated weed management (IWM) in minimizing nutrient competition from weeds and ensuring optimal nutrient availability for the rice crop, as supported [7], [8], [9]. IWM strategies, which combine herbicide application with manual interventions, provide a sustainable and cost-effective approach to weed control, improving crop nutrient uptake and overall productivity.

Nutrient Uptake of Rice

The data presented in (Table 2) reveals the significant effects of various weed management practices on nitrogen (N), phosphorus (P), and potassium (K) uptake in rice grain and straw at harvest in 2022 and 2023. The weedy check treatment (T1: No weed control) exhibited the lowest nutrient uptake, with nitrogen uptake in grains at 37.8 kg ha^{-1} in 2022 and 41.1 kg ha^{-1} in 2023, and in straw at 21.3 kg ha^{-1} and 23.2 kg ha^{-1} in 2022 and 2023, respectively. This treatment also had minimal phosphorus and potassium uptake, highlighting the detrimental impact of unchecked weed growth on nutrient availability for rice. In contrast, the weed-free treatment (T2: Complete weed removal) showed the highest nutrient uptake, with nitrogen uptake in grains at 65.1 kg ha^{-1} in 2022 and 70.5 kg ha^{-1} in 2023, and phosphorus and potassium levels similarly high, emphasizing the importance of eliminating weeds to maximize nutrient absorption. The farmer's practice (T3: One hand weeding at 40 DAT) moderately improved nutrient uptake compared to the weedy check, with nitrogen uptake in grains at 46.0 kg ha^{-1} in 2022 and 50.0 kg ha^{-1} in 2023. The application of Pyrazosulfuron 150 g a.i. ha^{-1} as pre-emergence (T4) further increased nutrient uptake, and when combined with one hand weeding at 40 DAT (T5), nutrient uptake improved even more, reaching nitrogen uptake levels of 58.1 kg ha^{-1} in 2022 and 62.4 kg ha^{-1} in 2023. Similarly, the post-emergence application of Bispyribac Sodium 25 g a.i. ha^{-1} at 15 DAT (T6) enhanced nutrient uptake, which was further boosted when combined with hand weeding (T7). Treatments involving Ethoxy sulfuron 20 g a.i. ha^{-1} as pre-emergence (T8) and its combination with one hand weeding (T9), as well as Penoxsulam 22 g a.i. ha^{-1} as post-emergence (T10) and its combination with hand weeding (T11), also demonstrated improved nutrient uptake compared to the weedy check, though the results were less pronounced than the Pyrazosulfuron and Bispyribac sodium treatments. The highest nutrient uptake was recorded in the treatment combining Pyrazosulfuron 150 g a.i. ha^{-1} (pre-emergence) + Penoxsulam 22 g a.i. ha^{-1} (post-emergence) + one hand weeding (T12), with nitrogen uptake in grains at 62.7 kg ha^{-1} in 2022 and 67.4 kg ha^{-1} in 2023. This integrated treatment demonstrated superior weed control, thereby enhancing nutrient availability for rice, supporting previous research findings that combining chemical and manual weed control methods is the most effective strategy for optimizing nutrient uptake and rice yields [9], [10],[11].

Table :1 Effect of weed management practices on nutrient uptake (kg ha^{-1}) of weeds at 90 Days

	Treatments	Nutrient uptake (kg ha^{-1})					
		Nitrogen		Phosphorus		Potassium	
		2022	**2023**	**2022**	**2023**	**2022**	**2023**
T_1	Weedy check	29.3	36.8	8.0	10.4	30.5	37.9
T_2	Weed free	0.0	0.0	0.0	0.0	0.0	0.0
T_3	Farmers practices (One hand weeding 40 DAT)	13.1	16.5	3.5	4.5	14.4	17.9
T_4	Pyrazosulfuron 150 g a.i. ha^{-1} (Pre emergence)	8.4	10.6	1.9	2.5	9.4	11.7
T_5	Pyrazosulfuron 150 g a.i. ha^{-1} (Pre emergence) + one hand weeding 40 DAT	7.4	9.3	1.7	2.2	8.6	10.7
T_6	Bispyribac Sodium @25 g a.i. ha^{-1} 15 DAT (Post- emergence)	11.6	14.6	2.8	3.7	12.9	16.0
T_7	Bispyribac Sodium @25 g a.i. ha^{-1} 15 DAT (Post- emergence) + one hand weeding 40 DAT	7.9	10.0	1.8	2.4	9.2	11.5
T_8	Ethoxy Sulfuron @20g a.i. ha^{-1} (pre- emergence)	12.4	15.6	3.2	4.2	13.6	16.9
T_9	Ethoxy Sulfuron @20g a.i. ha^{-1} (pre- emergence) + + one hand weeding 40 DAT	13.6	17.1	3.8	4.9	14.9	18.5
T_{10}	Penoxsulam 22 g a.i. ha^{-1} (post emergence)	11.3	14.1	2.7	3.5	12.5	15.6
T_{11}	Penoxsulam 22 g a.i. ha^{-1} (post emergence) + One hand weeding	7.1	8.9	1.5	2.0	8.0	9.9
T_{12}	Pyrazosulfuron 150 g ai.ha^{-1} (pre emergence) + Penoxsulam 22 g a.i. ha^{-1} post emergence + One hand weeding	6.0	7.6	1.3	1.7	6.9	8.6
	SEm+	**0.42**	**0.53**	**0.11**	**0.14**	**0.46**	**0.57**
	C.D.(P=0.05)	**1.21**	**1.52**	**0.31**	**0.41**	**1.32**	**1.64**

Table :2 Effect of weed management practices on N, P & K uptake (kg ha^{-1}) in rice grain & straw at harvest

	Treatments	Nutrient uptake (kg ha^{-1})											
		Nitrogen				Phosphorus				Potassium			
		Grains		Straw		Grains		Straw		Grains		Straw	
		2022	2023	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023
T_1	Weedy check	37.8	41.1	21.3	23.2	7.7	8.4	5.0	5.8	9.0	10.0	64.4	68.4
T_2	Weed free	65.1	70.5	32.7	35.0	17.5	19.3	10.7	11.7	17.5	19.3	93.7	99.1
T_3	Farmers practices (One hand weeding 40 DAT)	46.0	50.0	25.0	26.7	10.1	11.0	6.1	6.8	10.9	12.1	76.1	80.1
T_4	Pyrazosulfuron 150 g a.i. ha^{-1} (Pre emergence)	53.1	58.1	27.9	29.6	12.2	13.7	7.8	8.5	13.0	14.5	82.9	86.7
T_5	Pyrazosulfuron 150 g a.i. ha^{-1} (Pre emergence) + one hand weeding 40 DAT	58.1	62.4	29.6	31.8	13.5	14.9	8.7	9.7	14.4	15.8	86.0	91.2
T_6	Bispyribac Sodium @25 g a.i. ha^{-1} 15 DAT (Post- emergence)	49.3	52.9	26.7	28.6	11.2	11.9	7.0	7.8	11.9	13.1	80.6	85.2
T_7	Bispyribac Sodium @25 g a.i. ha^{-1} 15 DAT (Post- emergence) + one hand weeding 40 DAT	54.4	59.2	28.9	31.0	12.8	14.3	7.9	8.7	13.6	15.1	84.8	89.5
T_8	Ethoxy Sulfuron @20g a.i. ha^{-1} (pre-emergence)	46.8	50.9	26.5	28.4	10.2	11.1	7.0	7.8	11.0	12.3	79.6	84.0
T_9	Ethoxy Sulfuron @20g a.i. ha^{-1} (pre-emergence) + one hand weeding 40 DAT	43.8	47.7	24.1	26.1	9.4	10.2	5.9	6.7	10.4	11.6	73.0	77.7
T_{10}	Penoxsulam 22 g a.i. ha^{-1} (post emergence)	50.7	54.8	27.3	29.3	11.6	12.9	7.0	7.8	12.4	13.7	80.8	85.4
T_{11}	Penoxsulam 22 g a.i. ha^{-1} (post emergence) + One hand weeding	59.2	64.6	31.6	34.0	14.2	15.9	9.1	10.1	15.1	16.8	91.4	97.0
T_{12}	Pyrazosulfuron 150 g ai.ha^{-1} (pre emergence) + Penoxsulam 22 g a.i. ha^{-1} post emergence + One hand weeding	62.7	67.4	31.9	34.4	15.0	16.5	9.9	11.0	15.9	17.5	92.7	98.7
	SEm+	**1.86**	**2.02**	**0.99**	**1.06**	**0.43**	**0.48**	**0.27**	**0.30**	**0.46**	**0.51**	**2.92**	**3.09**
	C.D.(P=0.05)	**5.34**	**5.79**	**2.83**	**3.04**	**1.24**	**1.37**	**0.79**	**0.87**	**1.32**	**1.46**	**8.38**	**8.86**

Conclusion

The study demonstrates that integrated weed management practices significantly improve nutrient uptake in rice by reducing competition from weeds. The combination of Pyrazosulfuron 150 g a.i. ha^{-1} (pre-emergence) and Penoxsulam 22 g a.i. ha^{-1} (post-emergence), along with one hand weeding at 40 DAT proved to be the most effective resulting in the highest nutrient uptake and improved crop productivity. The weed-free treatment also showed excellent results, underscoring the importance of complete weed control. These findings suggest that combining chemical and manual weed control methods offers a sustainable and efficient approach to optimize nutrient availability, thereby enhancing rice yield and productivity. This integrated approach provides a balanced, cost-effective solution to managing weed competition in rice cultivation.

Disclaimer (Artificial intelligence)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc.) and text-to-image generators have been used during the writing or editing of this manuscript.

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