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Raghuveer M
Ph.D. Scholar, Department of Agronomy, College of Agriculture, KSNUAHS, Shivamogga, Karnataka, India

CJ Sridhara
Professor and Head, Department of Agronomy, College of Agriculture, KSNUAHS, Shivamogga, Karnataka, India

GK Girijesh
Professor, Department of Agronomy, College of Agriculture, KSNUAHS, Shivamogga, Karnataka, India

S Sridhara
Professor, Department of Agronomy, College of Agriculture, KSNUAHS, Shivamogga, Karnataka, India

Nandish MS
Professor, Department of Agricultural Microbiology, College of Agriculture, KSNUAHS, Shivamogga, Karnataka, India

KT Gurumurthy
Professor, Department of Soil Science, College of Agriculture, KSNUAHS, Shivamogga, Karnataka, India

Corresponding Author:
Raghuveer M
Ph.D. Scholar, Department of Agronomy, College of Agriculture, KSNUAHS, Shivamogga, Karnataka, India

Nutrient uptake by weeds as influenced by nutrient levels and weed management practices in aerobic rice

Raghuveer M, CJ Sridhara, GK Girijesh, S Sridhara, Nandish MS and KT Gurumurthy

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Abstract
Weed crop competition for nutrients is a major constraint in aerobic rice production, especially under sub-optimal nutrient supply and inadequate weed management. A field experiment was conducted during *Kharif* 2023 and 2024 at the Zonal Agricultural and Horticultural Research Station, Navile, Shivamogga, to evaluate the influence of nutrient levels and weed management practices on nutrient uptake by weeds in aerobic rice. The experiment was laid out in a factorial randomized block design with three nutrient levels (N_1: 75:37.5:37.5 NPK kg ha^{-1}, N_2: 100:50:50 NPK kg ha^{-1}, N_3: 125:62.5:62.5 NPK kg ha^{-1}) and four weed management practices (W_1: Hand weeding + Intercultivation (20 and 40 DAS), W_2: Pyrazosulfuron ethyl 10% WP @ 100 gm ha^{-1} (PE) + sunhemp, W_3: Pyrazosulfuron ethyl 10% WP @ 100 gm ha^{-1} (PE) + Bispyribac sodium 10 SL 0.4 ml ltr^{-1} (POE), W_4: Weedy check). Results revealed that weed nutrient uptake increased significantly with higher nutrient levels, as enhanced soil nutrient availability stimulated vigorous weed growth. Across both years, the highest nutrient uptake by weeds was recorded under N_3 combined with the weedy check. Effective herbicide treatments reduced N, P and K removal by weeds by restricting weed density and biomass throughout the crop growth period. Among weed flora, sedges contributed the highest share of total NPK uptake, followed by grasses and broad-leaved weeds. Interaction effects (N × W) were significant for all nutrient uptake parameters, confirming that nutrient application without proper weed control aggravates nutrient losses to weeds. Overall, the study highlights that integrated weed management combined with optimal nutrient application (125:62.5:62.5 NPK kg ha^{-1}) is essential to minimize nutrient depletion by weeds and improve nutrient use efficiency in aerobic rice systems.

Keywords: Aerobic rice, nutrient uptake, weed management, herbicides, pyrazosulfuron-ethyl, bispyribac sodium, sunhemp, integrated weed management

Introduction
Aerobic rice has emerged as a promising production system to address the challenges of water scarcity, labour shortage, and increasing climatic variability in rice-growing regions. Unlike conventional puddled transplanted rice, aerobic rice is cultivated under non-flooded, well-drained soil conditions using high-yielding varieties adapted to aerobic environments. Although this system saves 30-50% of irrigation water and improves soil physical properties, it is highly prone to weed infestation due to the absence of standing water, which normally suppresses weed emergence in lowland rice. Consequently, nutrient competition between weeds and the crop becomes a major constraint to productivity in aerobic rice ecosystems (Kumar *et al.*, 2020) [4].

Nutrient uptake by weeds directly affects crop growth, yield formation, and nutrient-use efficiency. Weeds often possess aggressive growth habits, faster early establishment, and deeper root systems, enabling them to capture a substantial proportion of applied nutrients. Studies have reported that nutrient uptake by dominant weed flora may exceed that of the crop during early growth stages, resulting in reduced tillering, smaller leaf area, and lower biomass accumulation in aerobic rice (Yadav *et al.*, 2017) [10]. The intensity of this competition is further influenced by the quantity of nutrients supplied through fertilizers. Higher nutrient availability may favour both crop and weeds, but in poorly managed fields, weeds extract a disproportionate share of nitrogen, phosphorus, and potassium (Surendran *et al.*, 2021) [8].

Weed management practices play a crucial role in minimizing nutrient loss to weeds. Integrated approaches involving pre-emergence (PE) and post-emergence (POE) herbicides, mechanical

weeding, and cover crops such as sunhemp have shown potential in reducing weed biomass and nutrient removal. Among chemical options, Pyrazosulfuron-ethyl (10% WP) as PE herbicide and Bispyribac sodium (10% SL) as POE herbicide are widely recommended for the aerobic rice system due to their broad-spectrum control of sedges, grasses, and broad-leaved weeds. However, their efficacy may vary depending on soil moisture, weed flora composition, herbicide sequence, and nutrient availability (Reddy *et al.*, 2021) [6].

Understanding nutrient uptake by weeds under different fertilizer levels and weed management practices is essential to quantify nutrient losses, optimize fertilizer recommendations, and improve nutrient-use efficiency in aerobic rice. Despite several studies on weed dynamics and yield response, limited information exists on how nutrient levels interact with weed management strategies to influence nutrient extraction by weeds in aerobic rice production systems. Such information is critical for developing site-specific nutrient and weed management recommendations to enhance crop competitiveness and reduce nutrient wastage (Wang *et al.*, 2021) [9].

Therefore, the present investigation was undertaken to assess the influence of varying nutrient levels and weed management practices on nitrogen, phosphorus, and potassium uptake by weeds in aerobic rice during two consecutive seasons. The study aims to quantify nutrient losses to weeds and identify the most effective nutrient weed management combinations for sustaining productivity and nutrient-use efficiency under aerobic cultivation.

Materials and Methods

The field experiment was conducted during the summer seasons of 2023 and 2024 at the Zonal Agricultural and Horticultural Research Station (ZAHRS), Navile, Shivamogga, Karnataka, India, to evaluate nutrient uptake by weeds in aerobic rice under different nutrient and weed management practices. The soil of the experimental site was red sandy loam, low in nitrogen, high in phosphorus and medium in potassium, with a pH of 5.89. The study was laid out in a factorial randomized block design with three replications, comprising three nutrient levels (N_1: 75:37.5:37.5, N_2: 100:50:50 and N_3: 125:62.5:62.5 NPK kg ha^{-1}) assigned as main plots and four weed management practices (W_1: hand weeding + intercultivation at 20 and 40 DAS, W_2: pyrazosulfuron-ethyl 10% WP @ 100 g ha^{-1} + sunhemp, W_3: pyrazosulfuron-ethyl 10% WP @ 100 g ha^{-1} + bispyribac sodium 10% SL @ 0.4 mL L^{-1}, and W_4: weedy check) as subplots. Aerobic rice was grown under recommended agronomic practices and irrigated according soil conditions, with nitrogen applied in three splits (basal, active tillering, and panicle initiation) and phosphorus and potassium applied as basal doses. Weed samples were collected at peak vegetative stage using a 0.25 m^2 quadrat at two random locations per plot, uprooted, washed, oven-dried at 65°C for 48 hours, and analyzed for nutrient concentration, where nitrogen was estimated by the Kjeldahl method, phosphorus by the vanadomolybdate yellow colour method and potassium by flame photometry. Nutrient uptake by weeds was calculated using the formula:

$$\text{Nutrient uptake by weeds} = \frac{\text{Nutrinet content (\%) X Weed dry weight (kg ha}^{-1})}{100}$$

Data from both years were subjected to ANOVA appropriate for factorial design and treatment means were compared using the Critical Difference (CD) at 5% probability level. Pooled analysis over the two years was performed where year × treatment interaction was non-significant.

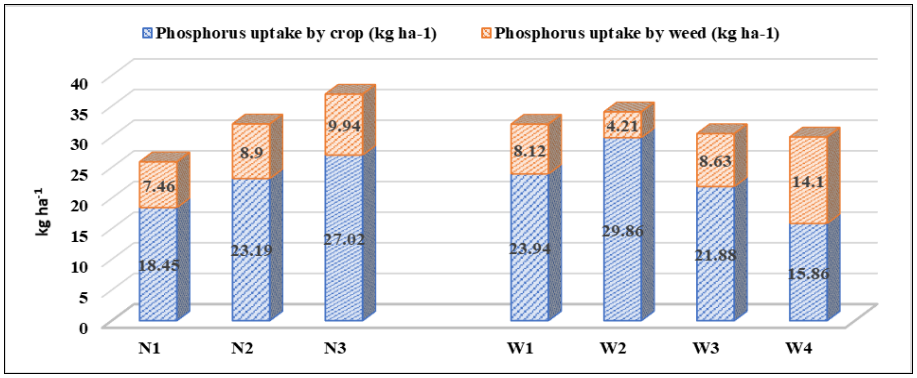
Results

Nutrient Uptake by Aerobic Rice

The nutrient uptake by aerobic rice significantly increased with higher nutrient levels and effective weed management practices. Among nutrient levels, N_3 (125:62.5:62.5 NPK kg ha^{-1}) recorded the highest uptake of nitrogen (99.36 kg ha^{-1}), phosphorus (27.02 kg ha^{-1}), and potassium (101.42 kg ha^{-1}) in pooled analysis, followed by N_2 and N_1. Similarly, weed management practices significantly influenced nutrient uptake, with W_2 (pyrazosulfuron-ethyl 10% WP + sunhemp) showing the highest uptake of N (107.64 kg ha^{-1}), P (29.86 kg ha^{-1}) and K (109.24 kg ha^{-1}), whereas the weedy check (W_4) recorded the lowest values. The interaction of nutrient levels and weed management practices revealed that N_3W_2 combination was most effective in enhancing nutrient uptake, whereas N_1W_4 showed the least nutrient accumulation. These results indicate that both optimum nutrient supply and effective weed control are critical for maximizing nutrient uptake by aerobic rice.

Nutrient Uptake by Weeds

Nutrient uptake by weeds also varied significantly with nutrient levels and weed management practices. Among nutrient levels, N_3 recorded the highest nitrogen (36.75 kg ha^{-1}), phosphorus (9.94 kg ha^{-1}), and potassium (26.87 kg ha^{-1}) uptake by weeds, while N_1 recorded the lowest. Weed management had a pronounced effect; W_4 (weedy check) exhibited the highest nutrient uptake by weeds (N: 58.04 kg ha^{-1}, P: 14.10 kg ha^{-1}, K: 44.63 kg ha^{-1}), indicating unrestricted weed growth under no control, whereas W_2 effectively reduced weed nutrient uptake (N: 16.26 kg ha^{-1}, P: 4.21 kg ha^{-1}, K: 11.96 kg ha^{-1}). The interaction effect showed that nutrient enrichment (N_3) in combination with poor weed control (W_4) led to the highest nutrient uptake by weeds, emphasizing that nutrient application in the absence of effective weed management may result in significant nutrient losses to weeds.



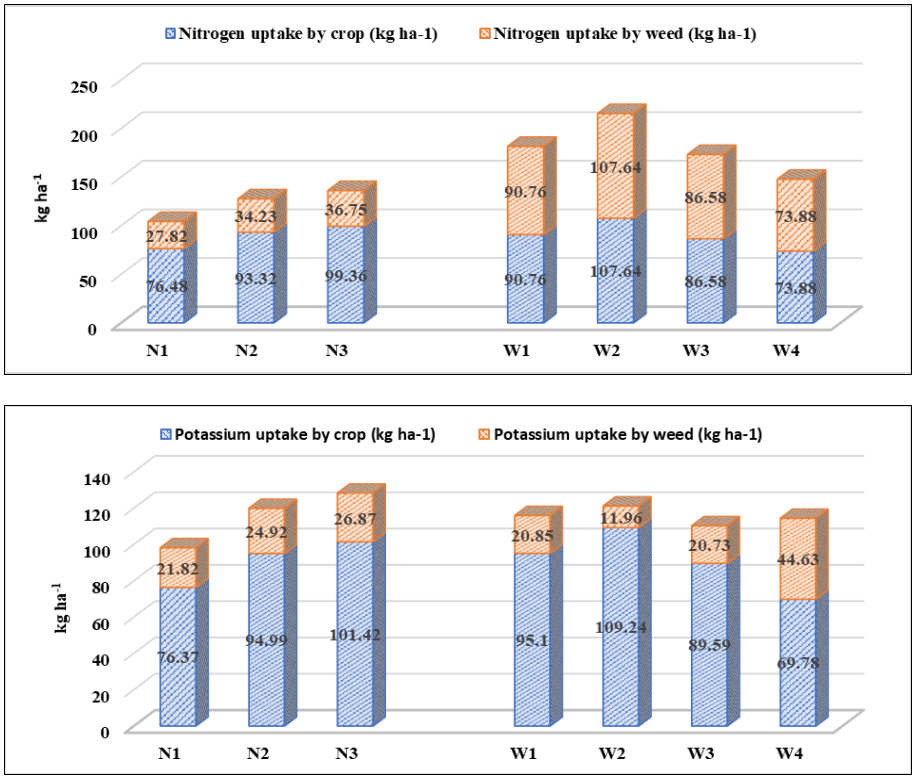


Fig 1: Nutrient uptake by aerobic rice and weeds as influenced by different nutrient levels and weed management practices

Discussion

The present study revealed that nutrient uptake by aerobic rice increased with higher nutrient levels and effective weed management practices. The highest uptake observed under N_3 (125:62.5:62.5 NPK kg ha^{-1}) aligns with previous reports indicating that adequate nutrient supply enhances crop growth, biomass accumulation and nutrient absorption (Singh *et al.*, 2025; Kumar *et al.*, 2023) [7, 5]. Similarly, weed management using herbicides in combination with cover crops (W_2: pyrazosulfuron-ethyl + sunhemp) significantly improved nutrient uptake by rice compared to the weedy check. This is attributed to reduced competition for soil nutrients, light, and space, allowing rice plants to utilize nutrients more efficiently (Chauhan and Johnson, 2011) [2].

Conversely, nutrient uptake by weeds was highest under the weedy check (W_4), particularly at higher nutrient levels, indicating that unregulated weed growth can sequester substantial amounts of N, P and K, thereby reducing nutrient availability to the crop. This emphasizes the importance of integrated weed management, especially under high fertility conditions, to minimize nutrient losses and enhance crop productivity. The interaction effects also highlighted that optimal nutrient management alone is insufficient if weeds are not effectively controlled, as weeds can act as strong nutrient sinks. Overall, these findings demonstrate that synchronized nutrient and weed management strategies are essential to maximize nutrient use efficiency, reduce losses to weeds, and ensure sustainable productivity in aerobic rice systems (Hittalamani *et al.*, 2024) [3].

Conclusion

The study demonstrated that nutrient uptake by aerobic rice was significantly enhanced with higher nutrient levels and effective weed management practices. The combination of N_3 (125:62.5:62.5 NPK kg ha^{-1}) and W_2 (pyrazosulfuron-ethyl + sunhemp) was most effective in maximizing nitrogen, phosphorus, and potassium accumulation in rice, while uncontrolled weeds (W_4) significantly increased nutrient removal by weeds, reducing crop nutrient availability. These results highlight the importance of integrated nutrient and weed management strategies for improving nutrient use efficiency and sustaining productivity in aerobic rice systems. Proper synchronization of fertilizer application with effective weed control can minimize nutrient losses to weeds and optimize crop performance.

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