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Evaluation of drone-based herbicide application on economic indices and yield of transplanted rice (*Oryza sativa* L.)

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ABSTRACT

A field experiment was conducted at Rice Research Centre, Agriculture Research Institute, Rajendranagar, Hyderabad during kharif, (2022) to assess the post emergence herbicide efficacy for drone spraying in transplanted rice (*Oryza sativa* L.). The experiment was laid out in randomized block design with 7 treatments and replicated thrice. Results revealed that the economic analysis clearly demonstrated that effective weed management substantially improved the profitability of rice production. Weed-free hand weeding at 20, 40 and 60 DAT (T_6) recorded the highest gross and net returns owing to its superior weed control and higher grain yield. However, the higher labour requirement and associated cost of hand weeding reduced its economic efficiency. Among the herbicide-based treatments, drone application of penoxsulam 1.02% + cyhalofop-butyl 5.1% OD @ 120 g a.i. ha⁻¹ (T_3) recorded the highest benefit–cost ratio (2.38), followed by the corresponding knapsack application (T_1) with a B:C ratio of 2.37. The comparatively lower cost of herbicide application through drone technology contributed to its greater economic advantage over knapsack application. In contrast, the unweeded control (T_7) recorded the lowest gross returns, net returns and B:C ratio (1.11) due to severe crop–weed competition. Therefore, drone-based application of penoxsulam 1.02% + cyhalofop-butyl 5.1% OD @ 120 g a.i. ha⁻¹ can be considered a cost-effective and economically efficient weed management option in rice, offering a favourable balance between crop productivity, weed control and production cost.

Keywords: Unmanned Aerial Vehicle, Drone, Cost of cultivation, B:C ratio, Gross returns and net returns

Introduction

Rice (*Oryza sativa* L.) is the most extensively cultivated and consumed cereal crop worldwide, serving as a staple food for billions of people. In India, rice holds significant economic importance, providing direct employment to nearly 70% of the rural population (Saha *et al.*, 2017) [1]. Globally, China ranks first in rice consumption, with approximately 155 million metric tons consumed during 2022–2023, followed by India with about 108.5 million metric tons in the same period. In terms of production, China also led during the 2021–2022 crop year with over 148 million metric tons of milled rice, while India ranked second with more than 129 million metric tons. Overall, global milled rice production was estimated to exceed 502 million metric tons in 2022–2023.

Rice cultivation is constrained by several biotic and abiotic stresses, among which weeds are one of the most critical yield-limiting biotic factors. Weeds compete aggressively with rice plants for vital resources such as nutrients, moisture, and sunlight, thereby reducing crop productivity. Kumar *et al.* (2010) [2] reported that, in the absence of weed control, rice grain yield declined by 70.4% in 2006 and 67.4% in 2007 compared to effectively managed plots. Among different weed categories, grassy weeds exert the highest competitive pressure, followed by sedges and broadleaf weeds.

A drone, or Unmanned Aerial Vehicle (UAV), is an aircraft operated remotely using software-guided flight plans embedded within its system, supported by onboard sensors and the Global Positioning System (GPS). Owing to their high adaptability and precision, UAV platforms are emerging as an effective alternative for aerial pesticide application (Wang *et al.*, 2018) [3].

Initially developed for military purposes, UAVs have undergone significant transformation with advancements in sensor technologies, GPS, and accessible computing, leading to their widespread adoption beyond defense applications (Ehsani & Maja, 2013; Hogan *et al.*, 2017) [4, 5]. Owing to their versatility, drones provide an efficient and precise solution for aerial chemical spraying (Wang *et al.*, 2018) [3]. They also support farmers by saving time and facilitating a range of agricultural operations, including soil fertilization, spraying, irrigation, crop health monitoring, planting, and livestock tracking. Furthermore, drones can function effectively in challenging conditions such as wet or sloping terrains, reduce labour requirements, and enable site-specific applications.

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Materials and methods

A field experiment was conducted during the Kharif season of 2022 at the Rice Research Centre, Agricultural Research Institute, Rajendranagar, Hyderabad. The experimental site had clay loam soil with a neutral pH of 7.6, electrical conductivity (EC) of 0.71 dS m⁻¹, and organic carbon content of 0.45%. The soil was medium in available nitrogen (212 kg ha⁻¹), phosphorus (28.2 kg ha⁻¹), and high in potassium (452.6 kg ha⁻¹).

The experiment was laid out in a randomized block design (RBD) comprising seven treatments with three replications. The rice variety RNR-15048 was transplanted at a seed rate of 50 kg ha⁻¹, maintaining a spacing of 15 cm × 15 cm with two seedlings per hill. Nutrient management involved the application of 120:60:40 kg ha⁻¹ of N, P₂O₅, and K₂O through urea, single super phosphate, and muriate of potash. The full dose of phosphorus was applied as a basal application, while nitrogen was applied in three equal splits at transplanting, maximum tillering, and panicle initiation stages. Potassium was applied in two equal splits at transplanting and panicle initiation.

Herbicides were applied at different crop stages, with pre-emergence (PE) herbicide applied 3 days after transplanting (DAT) and post-emergence (PoE) herbicide applied at 30 DAT. For ground application, 500 L ha⁻¹ of spray fluid was used with a flat-fan nozzle-fitted knapsack sprayer, whereas drone application utilized 40 L ha⁻¹ of spray volume.

Observations were recorded on key growth and yield parameters, including plant height (cm), number of tillers (m⁻²), number of panicles (m⁻²) at harvest, grain yield (kg ha⁻¹), and weed dry matter at 60 DAT.

Table 1. Details of the treatments

Treatment No.	Treatment details
T ₁	Application of penoxsulam 1.02 % + cyhalofop-butyl 5.1% OD @ 120 g a.i ha ⁻¹ using knapsack sprayer.
T ₂	Application of penoxsulam 1.02 % + cyhalofop-butyl 5.1% OD @ 90 g a.i ha ⁻¹ using drone.
T ₃	Application of penoxsulam 1.02 % + cyhalofop-butyl 5.1% OD @ 120 g a.i ha ⁻¹ using drone.
T ₄	Application of penoxsulam 1.02 % + cyhalofop-butyl 5.1% OD @ 150 g a.i ha ⁻¹ using drone.
T ₅	Application of penoxsulam 1.02 % + cyhalofop-butyl 5.1% OD @ 180 g a.i ha ⁻¹ using drone.
T ₆	Weed free (Hand weeding at 20, 40 and 60 DAT)
T ₇	Unweeded control

Results & discussion

Economics as influenced by different weed management practices

The effectiveness of any production system is ultimately evaluated on the basis of economics. The economic indicators such as gross returns (₹ ha⁻¹), net returns (₹ ha⁻¹) and B:C ratio were worked out and these indicators were analysed statistically and presented in the Table 2. Significantly highest gross returns were obtained with T₆ (weed free hand weeding at 20, 40 and 60 DAT) it was statistically on par with T₅ (application of penoxsulam 1.02% + cyhalofop-butyl 5.1% OD @ 180 g a.i ha⁻¹ using drone), T₁ (application of penoxsulam 1.02% + cyhalofop-butyl 5.1% OD @ 120 g a.i ha⁻¹ using knapsack sprayer), T₄ (application of penoxsulam 1.02% + cyhalofop-butyl 5.1% OD @ 150 g a.i ha⁻¹ using drone), T₃ (application of penoxsulam 1.02% + cyhalofop-butyl 5.1% OD @ 120 g a.i ha⁻¹ using drone) followed by T₂ (application of penoxsulam 1.02% + cyhalofop-butyl 5.1% OD @ 90 g a.i ha⁻¹ using drone). The lowest gross returns were obtained with T₇ (unweeded control). However, in terms of net returns higher net returns was obtained with T₆ (weed free hand weeding at 20, 40

and 60 DAT), it was statistically on par with T₅ (application of penoxsulam 1.02% + cyhalofop-butyl 5.1% OD @ 180 g a.i ha⁻¹ using drone), T₁ (application of penoxsulam 1.02% + cyhalofop-butyl 5.1% OD @ 120 g a.i ha⁻¹ using knapsack sprayer), T₄ (application of penoxsulam 1.02% + cyhalofop-butyl 5.1% OD @ 150 g a.i ha⁻¹ using drone) and T₃ (application of penoxsulam 1.02% + cyhalofop-butyl 5.1% OD @ 120 g a.i ha⁻¹ using drone) followed by T₂ (application of penoxsulam 1.02% + cyhalofop-butyl 5.1% OD @ 90 g a.i ha⁻¹ using drone). The lowest net returns were obtained with T₇ (unweeded control).

Similarly, higher benefit cost ratio was recorded (2.38) in T₃ (application of penoxsulam 1.02% + cyhalofop-butyl 5.1% OD @ 120 g a.i ha⁻¹ using drone) followed by T₁ (application of penoxsulam 1.02% + cyhalofop-butyl 5.1% OD @ 120 g a.i ha⁻¹ using knapsack sprayer) (2.37) and lower B:C ratio was noticed with un weeded control (1.11) because severe competition for nutrients throughout the crop growing season. Different weed management practices maintained less crop weed competition and higher nutrient availability which resulted in higher yields and high returns. Similar results were reported by Ramachandra *et al.* (2014) [6], Yadav *et al.* (2018b) [7] and Yogananda *et al.* (2019) [8].

The herbicide application cost was comparatively more for knapsack (12 to 23%) than drone application. It was attributed to increased labour wages for herbicide application. Garre and Harish (2018) reported that the production cost can be reduced up to 20% through drone application of pesticides. The highest grain yield and gross return were recorded in weed free hand weeding. However, the high incurred cost for weed control resulted in lesser net return and benefit cost ratio (BCR) than all herbicide treated plots. Similar finding were reported by Paul *et al.* (2023) [9].

Grain yield (kg ha⁻¹)

The data pertaining to grain yield was significantly influenced with various weed management practices was analysed statistically and results were presented in Table 3.

Rice grain yield was significantly higher in T₆ (weed-free condition maintained through hand weeding at 20, 40, and 60 DAT) and was statistically comparable with T₅ (application of penoxsulam 1.02% + cyhalofop-butyl 5.1% OD @ 180 g a.i ha⁻¹ using a drone), T₁ (application @ 120 g a.i ha⁻¹ using a knapsack sprayer), T₄ (application @ 150 g a.i ha⁻¹ using a drone), and T₃ (application @ 120 g a.i ha⁻¹ using a drone). This was followed by a significantly lower grain yield in T₂ (application @ 90 g a.i ha⁻¹ using a drone), while the lowest grain yield was recorded in T₇ (unweeded control).

The results revealed that reducing the recommended dose of post-emergence herbicide by 25% when applied through a drone (T₂) led to a 22.82% decline in rice grain yield, indicating that lowering the herbicide dose adversely affects yield performance. In contrast, increasing the recommended dose by 25% (T₄) and 50% (T₅) resulted in marginal yield improvements of 2.53% and 3.36%, respectively; however, these were statistically on par with the recommended dose (T₃). The findings clearly demonstrate that a reduction in herbicide quantity significantly reduced grain yield (4653 kg ha⁻¹) under T₂ treatment (Paul *et al.*, 2023) [9].

Efficient utilization of light, water, and nutrients under conditions of low weed density and reduced weed dry matter resulted in the highest grain yield (6318 kg ha⁻¹) with hand weeding at 20, 40, and 60 DAT. Effective weed management practices not only minimized weed density and biomass but also enhanced the crop's ability to utilize available resources efficiently. This improvement in resource use led to better growth parameters and yield attributes, ultimately resulting in higher grain yield compared to the unweeded control. Similar findings have been reported by Chowdhary and Dixit (2018) [10], Kashid (2019) [11], Singh *et al.* (2019) [12], and Ramesha *et al.* (2019) [13].

The lowest rice grain yield was recorded under the unweeded control, primarily due to high weed density and biomass, which adversely affected all yield parameters. Similar findings were reported by Atheena *et al.* (2017) [14] and Venkatesh *et al.* (2019) [15].

Table 2. Cost of cultivation, gross returns, net returns and B:C of rice as influenced as influenced by weed management practices during *kharif*, 2022

Treatments	Cost of cultivation (₹ ha ⁻¹)	Gross returns (₹ ha ⁻¹)	Net returns (₹ ha ⁻¹)	B:C ratio
T ₁ : Application of penoxsulam 1.02% + cyhalofop-butyl 5.1% OD @ 120 g a.i ha ⁻¹ using knapsack sprayer.	57900	137456	79556	2.37
T ₂ : Application of penoxsulam 1.02% + cyhalofop-butyl 5.1% OD @ 90 g a.i ha ⁻¹ using drone.	56075	104567	48492	1.86
T ₃ : Application of penoxsulam 1.02% + cyhalofop-butyl 5.1% OD @ 120 g a.i ha ⁻¹ using drone.	57025	135455	78430	2.38
T ₄ : Application of penoxsulam 1.02% + cyhalofop-butyl 5.1% OD @ 150 g a.i ha ⁻¹ using drone.	57975	136755	78780	2.36
T ₅ : Application of penoxsulam 1.02% + cyhalofop-butyl 5.1% OD @ 180 g a.i ha ⁻¹ using drone.	58925	138142	79217	2.34
T ₆ : Weed free (Hand weeding at 20, 40 and 60 DAT)	63000	142766	79766	2.27
T ₇ : Unweeded control	53000	58656	5656	1.11
SE(m)±		2790	1817	0.11
CD (P = 0.05)		8100	5251	0.35

Table 3. Grain yield (kg ha⁻¹) of rice as influenced by different weed management practices during *kharif*, 2022

Treatments	Grain yield kg ha ⁻¹
T ₁ : Application of penoxsulam 1.02% + cyhalofop-butyl 5.1% OD @ 120 g a.i ha ⁻¹ using knapsack sprayer.	6207
T ₂ : Application of penoxsulam 1.02% + cyhalofop-butyl 5.1% OD @ 90 g a.i ha ⁻¹ using drone.	4653
T ₃ : Application of penoxsulam 1.02% + cyhalofop-butyl 5.1% OD @ 120 g a.i ha ⁻¹ using drone.	6029
T ₄ : Application of penoxsulam 1.02% + cyhalofop-butyl 5.1% OD @ 150 g a.i ha ⁻¹ using drone.	6186
T ₅ : Application of penoxsulam 1.02% + cyhalofop-butyl 5.1% OD @ 180 g a.i ha ⁻¹ using drone.	6239
T ₆ : Weed free (Hand weeding at 20, 40 and 60 DAT)	6318
T ₇ : Unweeded control	2570
SE(m)±	142.4
CD (P = 0.05)	438

Conclusions

The economic analysis clearly demonstrated that effective weed management substantially improved the profitability of rice production. Weed-free hand weeding at 20, 40 and 60 DAT (T₆) recorded the highest gross and net returns owing to its superior weed control and higher grain yield. However, the higher labour requirement and associated cost of hand weeding reduced its economic efficiency. Among the herbicide-based treatments, drone application of penoxsulam 1.02% + cyhalofop-butyl 5.1% OD @ 120 g a.i. ha⁻¹ (T₃) recorded the highest benefit–cost ratio (2.38), followed by the corresponding knapsack application (T₁) with a B:C ratio of 2.37. The comparatively lower cost of herbicide application through drone technology contributed to its greater economic advantage over knapsack application. In contrast, the unweeded control (T₇) recorded the lowest gross returns,

net returns and B:C ratio (1.11) due to severe crop–weed competition. Therefore, drone-based application of penoxsulam 1.02% + cyhalofop-butyl 5.1% OD @ 120 g a.i. ha⁻¹ can be considered a cost-effective and economically efficient weed management option in rice, offering a favourable balance between crop productivity, weed control and production cost.

References

- Saha B, Panda P, Patra PS, Panda R, Kundu A, Roy AS, Mahato N. Effect of different levels of nitrogen on growth and yield of rice (*Oryza sativa* L.). cultivars under terai-agro climatic situation. *International Journal of Current Microbiology and Applied Sciences*. 2017;6(7):2408-2418.
- Kumar J, Singh D, Puniya R, Pandey PC. Effect of weed management practices on nutrient uptake by direct seeded rice. *Oryza*. 2010;47(4):291-294.
- Wang J, Lan Y, Zhang H, Zhang Y, Wen S, Yao W, Deng J. Drift and deposition of pesticide applied by UAV on pineapple plants under different meteorological conditions. *International Journal of Agricultural and Biological Engineering*. 2018;11(6):5-12.
- Ehsani R, Maja JM. The rise of small UAVs in precision agriculture. *Resource Magazine*. 2013;20(4):18-19.
- Hogan S, Kelly N, Stark B, Chen Y. Unmanned aerial systems for agriculture and natural resources. *California Agriculture*. 2017;71(1):5-14.
- Ramachandra C, Shivakumar N, Ningaraju GK. Effect of herbicides and their combination on weed dynamics in rice-based cropping system. *Indian Journal of Weed Science*. 2014;46(2):123-1.
- Yadav D, Singh N, Anil Dhuan, Ashok yadav, Punia SS. Penoxsulam + cyhalofop-butyl (premix) evaluation for control of complex weed flora in transplanted rice and its residual effects in rice-wheat cropping system. *Indian Journal of Weed Science*. 2018;50(4):333–339.
- Yogananda SB, Thimmegowda P, Shruthi GK. Sequential application of preand post-emergence herbicides for control of complex weed flora in dry direct-seeded rice under Cauvery command area of *Karnataka*. *Indian Journal of Weed Science*. 2019;51(2):111-115.

9. Paul R, Arthanari P, Pazhnivelan S, Kavitha R, Djanagoiraman M. Dronebased herbicide application for energy saving, higher weed control and economics in direct-seeded rice (*Oryza sativa* L.). Indian Journal of Agricultural Sciences. 2023;93(7):704–709.
10. Choudhary VK, Dixit A. Herbicide weed management on weed dynamics, crop growth and yield in direct-seeded rice. Indian Journal of Weed Science. 2018;50(1):6-12.
11. Kashid NV. Integration of post-emergence herbicide application with hand weeding for managing weeds in transplanted rice. Indian Journal of Weed Science. 2019;51(2):206-208.
12. Singh K, Singh S, Pannu RK. Efficacy of pendimethalin and cyhalofopbutyl+ penoxsulam against major grass weeds of direct-seeded rice. Indian Journal of Weed Science. 2019;51(3):227-231.
13. Ramesha YM, Anand SR, Krishnamurthy D, Bhanuvally M. Weed management effect to increase grain yield in dry direct-seeded rice. Indian Journal of Weed Science. 2019;51(1):6-9.
14. Atheena A, Prameela P, Menon VM. Tank mix application of cyhalofopbutyl with selected herbicides for weed control in wet-seeded rice. Indian Journal of Weed Science. 2017;49(3):283-286.
15. Venkatesh B, Parameshwari YS, Madhavi M, Ramprakash T. Performance of herbicides and herbicide mixtures on weed control in transplanted rice. Indian Journal of Weed Science. 2019;53(2):179–181.

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