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# Economic analysis of herbicide application using drones for weed control in barnyard millet: A profitability perspective

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## Abstract
Barnyard millet is a key nutri-cereal known for its high nutritional value, drought tolerance, short growth duration, and suitability to climate-smart farming. Although traditionally grown under rainfed conditions, it is increasingly cultivated with irrigation to maximize yield. However, under irrigated conditions, weed infestation becomes a major constraint, reducing yield and increasing labor costs due to reliance on manual weeding. As a result, chemical weed control is steadily replacing conventional methods. The success of chemical weed management largely depends on accurate herbicide dosage and proper application techniques. Drone-based spraying offers a highly precise method, but requires optimization of herbicide quantity and spray volume for each crop.

A study was carried out during the 2023-24 rabi season at ADAC&RI, TNAU, Tiruchirapalli, Tamil Nadu, using a Randomized Block Design (RBD) with three replications to assess the economic performance of drone-applied pre-emergence herbicides. The experiment included two doses of Pretilachlor (375 g/ha and 500 g/ha) combined with different spray volumes (40, 50, and 60 L/ha for drone spraying and 500 L/ha for manual application). These were compared against an unweeded control and the conventional knapsack sprayer treatment using Pretilachlor at 375 ml/ha with 500 L/ha spray volume. Weed control efficiency, grain yield, and economic return were recorded.

Findings showed that the best weed control (91.9% at 15 DAT), highest grain yield (2195 kg/ha), and a benefit-cost ratio of 2.0 were obtained with Pretilachlor at 500 g/ha applied using a drone with a spray volume of 40 L/ha. This treatment produced 1311 kg/ha more grain than the untreated control. Compared to manual spraying of Pretilachlor at the same dose (500 g/ha) with a 500 L/ha spray volume, drone application at 40 L/ha yielded an additional net benefit of ₹4,350 per hectare, along with more timely and safer herbicide application.

**Keywords:** Weed management, drone, pretilachlor, weed control efficiency, yield, economics

## Introduction
Barnyard millet (*Echinochloa frumentacea*) is an important nutricereal valued for its strong drought tolerance and short growing period of about 95-100 days, making it ideal for rainfed farming systems. It is widely recognized as a climate-resilient crop. Millets in general are known for their rapid growth and short duration, which help them thrive under adverse environmental conditions (Raundal *et al*., 2017) [1]. The popularity and demand for Barnyard millet have been increasing due to its exceptional nutritional qualities and diverse uses. Often referred to as a nutritional powerhouse, it serves as a staple nutricereal in many areas. Each 100 g of grain contains roughly 8.7% moisture, 10.1% protein, 6.7% crude fiber, 2.0% fat, 3.9% ash, and 68.8% carbohydrates, providing an energy value of 398 kcal. It also offers 12.5% dietary fiber, including 4.2% soluble fiber, along with essential minerals such as phosphorus (281 mg), iron (5 mg), magnesium (83 mg), and calcium (19 mg) (Kaur *et al*., 2020) [2].
Although Barnyard millet is predominantly cultivated by broadcasting in rainfed areas, this practice often leads to low yields due to poor germination, weak crop establishment, and inadequate adoption of recommended agronomic practices. Higher productivity can be achieved under irrigated conditions when the crop is established through direct sowing or transplanting,

combined with proper crop management. Transplanting is commonly preferred in irrigated systems as it enhances seed germination in nurseries, ensures the required plant population in the field, improves establishment, enhances growth parameters, and ultimately increases both grain and straw yields. Good establishment also minimizes the need for thinning and gap filling, helping maintain optimal crop stand (Dileep *et al*., 2018) [3].

However, weed infestation continues to be a major constraint in irrigated Barnyard millet cultivation, significantly reducing yields and raising production expenses. Effective weed control is essential for improving productivity and profitability. With rising labor shortages and the high cost of manual weeding, many farmers are shifting toward herbicide use. Drone-based herbicide application provides fast, precise spraying, reduces early crop-weed competition, and improves weed control efficiency and yield. Despite these benefits, effective drone use requires careful optimization of herbicide dose and spray volume to achieve uniform coverage and maximize weed suppression and economic returns. Therefore, this study was undertaken to determine the ideal herbicide rates and spray fluid volumes for drone-assisted chemical weed management in irrigated Barnyard millet.

## Materials and Methods

### Experimental Site

The field experiment was carried out during the Rabi season of 2023 at ADAC&RI, TNAU, Tiruchirappalli, Tamil Nadu, using the Barnyard millet variety MDU 1 as the test crop. The experimental site had sandy clay loam soil with moderate drainage and a pH of 8.6 (sodic soil), classified as Vetric Ustropept. The study aimed to determine the optimum herbicide dose for effective weed management in Barnyard millet using drone-based application and to standardize the spray fluid volume required for efficient herbicide delivery via drones.

### Weed control efficiency

Weed control efficiency was measured at 15, 30, and 45 days after sowing (DAS) using the formula given by Mani *et al*. (1973) [4].

$$\text{WCE (\%)} = \frac{Wpc - Wpt}{Wpc} \times 100 \qquad \text{(Eq. 1)}$$

Where,
Wpc = Weed density in control plot
Wpt= Weed density in treated plot

**Economics:** The economic analysis was carried out by considering input costs, labor wages, and the income generated from the market value of the harvested produce. Gross return, net return, and the benefit-cost ratio were calculated for each treatment using the standard formulas given below.

Gross return (Rs. /ha) =Economic yield (kg/ha) x Market value of the produce (Rs./Kg)

Net return (Rs./ha) = Gross return (Rs./ha)-Cost of cultivation (Rs./ha)

$$\text{BC ratio} = \frac{\text{Gross return (Rs.ha}-1)}{\text{Cost of cultivation (Rs.ha}-1)} \qquad \text{(Eq. 2)}$$

### Partial budgeting

Partial budgeting was used to evaluate the economic impact of the new technology compared to the existing practice. This method considers only the changes in costs and returns resulting from the new practice, rather than the total expenses. The outcome indicates whether adopting the new method will increase or decrease profitability relative to the current practice. In this study, the partial budget was computed using the cost of herbicides, spraying charges for each treatment, and their corresponding gross returns, with the recommended herbicide dose ($T_7$) taken as the reference or standard practice. The additional benefit was determined using the following formula.

Added benefit = (Added cost + Reduced return) - (Reduced cost + Added return) (Eq.3)

### Statistical analysis

The data collected for different parameters were statistically analyzed using the procedure described by Gomez and Gomez (1984) [5]. The observations were compiled, organized, and processed for statistical evaluation. A one-way ANOVA was performed using AGRES software to assess the treatment effects, and mean comparisons were made based on the critical difference (CD) at the 0.05% probability level. Differences that were not statistically significant were indicated as ‘NS’.

## Results and Discussion

### Weed Control Efficiency

The maximum weed control efficiencies—91.9%, 89.2%, and 82.8% at 15, 30, and 45 DAT, respectively—were achieved with the application of pre-emergence pretilachlor at 500 g/ha using a spray volume of 40 L/ha through drone spraying. This improved performance can be attributed to the uniform spray coverage and increased effectiveness of the herbicide. Such enhanced weed suppression led to reductions in both weed population and biomass (Kujur *et al*., 2019) [1]. Compared to conventional sprayers, unmanned aerial vehicles (UAVs) ensure more even liquid distribution and improved penetration, contributing to more precise herbicide application. However, weed control efficiency generally declines as the crop matures, likely due to the gradual increase in weed emergence and biomass over time.

**Table 1:** Effect of herbicide spray through drone on weed control efficiency in irrigated weed management.

| Treatments | | Weed Control Efficiency (%) | | |
|---|---|---|---|---|
| | | 15 DAT | 30 DAT | 45 DAT |
| $T_1$ | DS of PE Pretilachlor @ 500 g/ha with SF of 40 l/ha | 91.9 | 89.2 | 82.8 |
| $T_2$ | DS of PE Pretilachlor @ 500 g/ha with SF of 50 l/ha | 89.4 | 86.1 | 78.3 |
| $T_3$ | DS of PE Pretilachlor @ 500 g/ha with SF of 60 l/ha | 79.5 | 76.4 | 67.4 |
| $T_4$ | DS of PE Pretilachlor @ 375 g/ha with SF of 40 l/ha | 85.4 | 81.3 | 73.0 |
| $T_5$ | DS of PE Pretilachlor @ 375 g/ha with SF of 50 l/ha | 78.5 | 74.4 | 66.6 |
| $T_6$ | DS of PE Pretilachlor @ 375 g/ha with SF of 60 l/ha | 70.6 | 63.7 | 50.8 |
| $T_7$ | MS of PE Pretilachlor @ 500 g/ha with SF of 500 l/ha | 88.4 | 85.8 | 78.1 |
| $T_8$ | MS of PE Pretilachlor @ 375 g/ha with SF of 500 l/ha | 77.9 | 73.2 | 63.1 |
| $T_9$ | Unweeded Control | - | - | - |

## Yield

The unweeded control plot produced the lowest grain yield, measuring only 884 kg/ha. In India, unchecked weed growth has been reported to cause yield losses of up to 76% (Singh and Singh, 2004) [7]. In another study, the absence of weeding led to a 59.68% decline in grain yield and a 33.57% reduction in straw yield when compared to fields that received one inter-cultivation at 20 DAS and a hand weeding at 40 DAS (Kumar *et al*., 2019) [8]. Yield losses have been reported to reach as high as 84% in unweeded conditions (Ramamoorthy *et al*., 2002) [9]. In the present study, the highest grain yield of 2195 kg/ha was obtained from the pre-emergence application of pretilachlor at 500 g/ha using 40 L/ha of spray fluid applied through a drone.

**Table 2:** Effect of herbicide spray through drone on yield and economics in irrigated barnyard millet

| Treatments | Grain yield (kg/ha) | Cost of cultivation (Rs./ha) | Gross Income (Rs./ha) | Net Return (Rs./ha) | BCR |
|---|---|---|---|---|---|
| $T_1$ | 2195 | 27425 | 54875 | 27450 | 2.0 |
| $T_2$ | 2035 | 27425 | 50875 | 23450 | 1.9 |
| $T_3$ | 1548 | 27425 | 38700 | 11275 | 1.4 |
| $T_4$ | 1861 | 27265 | 46525 | 19260 | 1.7 |
| $T_5$ | 1532 | 27265 | 38300 | 11035 | 1.4 |
| $T_6$ | 1129 | 27265 | 28225 | 960 | 1.0 |
| $T_7$ | 2021 | 27975 | 50525 | 22550 | 1.8 |
| $T_8$ | 1524 | 27815 | 38100 | 10285 | 1.4 |
| $T_9$ | 884 | 25535 | 22100 | -3435 | 0.9 |
| SEd | 71 | | | | |
| CD (P=0.05) | 150 | | | | |

## Economics

The additional expenses incurred for weed management led to higher returns when compared to the unweeded control plot. The pre-emergence application of pretilachlor at 500 g/ha with 40 L/ha spray volume delivered via drone resulted in the highest net income of Rs. 2,74,251/ha and a BCR of 2.0. Drone-based herbicide application produced a substantial yield advantage over the unweeded control. It also generated greater net income than the conventional manual application of pretilachlor at 500 g/ha with 500 L/ha spray volume, while providing the added benefits of timely application and reduced health hazards for laborers. Drone-assisted spraying is increasingly recognized as a cost-efficient alternative to traditional manned aerial spraying and a highly effective replacement for manual herbicide application (Xiongkui *et al*., 2017) [10].

**Table 3:** Net change in income by drone method of application compared to manual method of spray

| Treatments | Added returns(A) | Reduced cost (B) | Additional cost (C) | Reduced returns (D) | Net change in income (A+B)-(C+D) |
|---|---|---|---|---|---|
| $T_1$ | 4350 | 550 | 0 | 0 | 4900 |
| $T_2$ | 350 | 550 | 0 | 0 | 900 |
| $T_3$ | 0 | 550 | 11825 | 0 | -11275 |
| $T_4$ | 0 | 710 | 4000 | 0 | -3290 |
| $T_5$ | 0 | 710 | 12225 | 0 | -11515 |
| $T_6$ | 0 | 710 | 22300 | 0 | -21590 |
| $T_7$ | - | - | - | - | - |
| $T_8$ | 0 | 160 | 12425 | 0 | -12265 |
| $T_9$ | 0 | 0 | 28425 | 0 | -28425 |

Advancements in artificial intelligence and modern weed management technologies provide highly efficient and environmentally sustainable approaches for controlling weed populations (Esposito *et al*., 2021) [11]. These innovations help reduce herbicide usage, lower environmental pollution, and enhance farm profitability (Manisankar *et al*., 2022) [12]. Drones significantly reduce labor requirements associated with manual spraying. Traditional methods, including manual and ground-based application, are labor-intensive and time-consuming, especially in larger fields. In contrast, drones deliver faster field coverage and more precise herbicide placement, leading to notable cost savings (Takekawa *et al*., 2023) [13]. By simplifying operations, drones also allow farmers to manage their time more efficiently. Moreover, drone-based herbicide spraying promotes sustainable agriculture by reducing the environmental footprint linked to energy-demanding conventional practices (Sahni *et al*., 2024) [14].

## Conclusion

The pre-emergence application of Pretilachlor at 500 g/ha with a spray volume of 40 L/ha at 3 DAT achieved high weed control efficiency (91.9%) at 15 DAT. This treatment also produced superior grain yield (2195 kg/ha) and a benefit-cost ratio of 2.0. The results suggest that applying Pretilachlor at 500 g/ha with 40 L/ha of spray fluid through drone spraying at 3 DAT, along with recommended agronomic practices, is vital for improving weed suppression, boosting yield, lowering production costs, and enhancing net income and BCR.

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## References

1. Raundal PU, Pawar PP, Musamade AM, Mahajan MS, Desale SB. Response of little millet varieties to different levels of fertilizers under rainfed condition. A Peer-Reviewed Multi-Disciplinary Int J. 2017;18.
2. Kaur H, Sharma S. An overview of Barnyard millet (*Echinochloa frumentacea*). J Pharmacogn Phytochem. 2020;9(4):819-22.

3. Dileep K, Pasupalak S, Baliarsingh A. Effect of establishment methods and sowing time on growth and yield of rice varieties (*Oryza sativa* L.). The Pharma Innov J. 2018;7:904-7.
4. Mani V, Malla M, Gautam KC, Bhagwandas B. Weed-killing chemicals in potato cultivation. 1973.
5. Gomez KA, Gomez AA. Statistical procedures for agricultural research. New York: John Wiley & Sons; 1984.
6. Kujur S, Singh VK, Gupta DK, Kumar S, Das D, Jena JJ. Integration of different weed management practices for increasing yield of finger millet (*Eleusine coracana* L. Gaertn). J Pharmacogn Phytochem. 2019;8:614-7.
7. Singh V, Singh M. Effect of Bispyribac sodium on transplanted rice and associated weeds. Indian J Weed Sci. 2004;36:190-2.
8. Kumar A, Paliwal A, Rawat L, Kumar P, Paliwal A, Chaudhary S. Barnyard millet (*Echinochloa frumentacea*) productivity enhancement through establishment methods and weed management practices under hilly rainfed conditions. Int J Chem Stud. 2019;7(2):1360-2.
9. Ramamoorthy K, Louurduraj AC, Sekhar MP. Weed management studies with pre-emergence Isoproturon in rainfed direct sown finger millet (*Eleusine coracana* Gaertn.). Madras Agric J. 2002;89:1.
10. Xiongkui H, Bonds J, Herbst A, Langenakens J. Recent development of unmanned aerial vehicle for plant protection in East Asia. Int J Agric Biol Eng. 2017;10:18-30.
11. Esposito M, Crimaldi M, Cirillo V, Sarghini F, Maggio A. Drone and sensor technology for sustainable weed management: A review. Curr Agric Biotechnol. 2021;8:1-11.
12. Manisankar G, Ghosh P, Malik GC, Banerjee M. Recent trends in chemical weed management: A review. The Pharma Innov J. 2022;11:745-53.
13. Takekawa JY, Hagani JS, Edmunds TJ, Collins JM, Chappell SC, Reynolds WH. The sky is not the limit: Use of a spray drone for precise application of herbicide and control of an invasive plant in managed wetlands. Remote Sens. 2023;15:3845.
14. Sahni RK, Kumar SP, Thorat D, Rajwade Y, Jyoti B, Ranjan J, *et al*. Drone spraying system for efficient agrochemical application in precision agriculture. In: Applications of Computer Vision and Drone Technology in Agriculture. 2024.