



Plant Archives

Journal homepage: <http://www.plantarchives.org>

DOI Url : <https://doi.org/10.51470/PLANTARCHIVES.2026.v26.no.2.103>

EFFICACY OF DRONE-APPLIED PROFENOPHOS AT DIFFERENT CONCENTRATIONS AGAINST RICE BLUE BEETLE, *Leptispa pygmaea* BALY

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(Date of Receiving-09-08-2026; Date of Revision-07-10-2026; Date of Acceptance-13-10-2026)

ABSTRACT

Rice blue beetle, *Leptispa pygmaea* Baly, is an important foliage-feeding pest of rice in the humid Konkan region of western India. A field experiment was conducted during *Kharif* 2025 to evaluate low-volume unmanned aerial vehicle (UAV) application of profenophos 50% emulsifiable concentrate (EC) at three concentration regimes and to compare treatment performance with conventional knapsack spraying and an untreated control. Five treatments were evaluated in a randomized block design with four replications: UAV application at 3000, 4000 and 5000 mL formulation ha⁻¹ using 30 L spray fluid ha⁻¹; knapsack application at 500 mL formulation ha⁻¹ using 500 L ha⁻¹ and an untreated control. Pretreatment infestation was statistically uniform. Thereafter, all insecticide treatments significantly reduced infestation relative to the untreated control. At 14 days after spraying (DAS), infestation was 1.43%, 1.16% and 0.86% under the 3000, 4000 and 5000 mL ha⁻¹ UAV treatments, respectively, compared with 4.95% under knapsack application and 18.90% in the untreated control. Corresponding reductions over control were 92.43%, 93.86%, 95.45% and 73.81%. Slight, temporary leaf yellowing occurred for 2-3 days, particularly at the highest UAV concentration, but plants recovered within 4-5 days and no persistent leaf burn, wilting, necrosis or stunting was observed. The results demonstrate a strong concentration-dependent suppression of *L. pygmaea* under low-volume UAV application. Because the UAV treatments received higher profenophos application rates than the knapsack treatment, their superior efficacy should be interpreted as the combined effects of application rate and spray delivery rather than application method alone.

Key words : Agricultural drone, Profenophos, Rice blue beetle, Phytotoxicity, Low-volume spraying.

Introduction

Rice is frequently exposed to insect-pest pressure from nursery establishment through crop maturity, and effective plant-protection operations are essential where pest populations exceed economically acceptable levels. In transplanted rice, however, conventional pesticide application can be difficult because standing water and dense crop growth restrict operator movement and increase the labor required for timely spraying. Agricultural UAVs offer a contrasting application approach in which relatively small carrier volumes can be delivered rapidly

without the operator walking through the crop. Reviews identify flight parameters, nozzle configuration and environmental conditions as interacting determinants of pesticide deposition and utilization efficiency (Hu *et al.*, 2022).

Field studies in rice have shown that UAV pesticide application can provide effective pest suppression when appropriate spray systems and operating conditions are used. Qin *et al.* (2016) demonstrated effective UAV-based insecticide application against rice planthoppers, while Sambaiah *et al.* (2022) reported successful UAV

management of rice leaf folder. More recent studies have shown that UAV configuration, atomization and flight velocity can influence both deposition and control efficacy in paddy rice (Huang *et al.*, 2023; Wongsuk *et al.*, 2024). Under Indian conditions, Ragiman *et al.* (2024) further demonstrated the practical potential of UAV-assisted pesticide application against several rice pests and diseases. Chen *et al.* (2020a) also examined how nozzle choice affected deposition and planthopper control at two rice growth stages, illustrating the need to evaluate biological efficacy alongside spray delivery.

The rice blue beetle, *Leptispa pygmaea* Baly (Coleoptera: Chrysomelidae), is a foliage-feeding pest reported from rice-growing areas of the Konkan region. Both adults and grubs scrape the green tissues of leaves, thereby reducing effective photosynthetic area. Species-specific management information is comparatively limited, although Japur *et al.* (2012) reported that profenophos 50% EC was among the most effective insecticidal treatments tested against *L. pygmaea* under rainfed rice conditions. Profenophos has also shown activity against other rice insect pests, with biological performance influenced by concentration and target pest (Hurali *et al.*, 2020).

UAV spraying differs fundamentally from conventional knapsack spraying in carrier volume and concentration of spray solution. This creates an important experimental consideration: when both application method and insecticide concentration differ among treatments, observed biological responses cannot be attributed solely to the spraying platform. Accordingly, comparison should focus on treatment regimes as actually applied, while separating application-rate effects from claims about application technology.

The present study evaluated three low-volume UAV concentration regimes of profenophos 50% EC against rice blue beetle and compared their field performance with a conventional knapsack treatment and an untreated control. The objectives were to quantify infestation from 1 to 14 days after spraying, calculate reduction over the untreated control and record visible phytotoxicity.

Materials and Methods

Experimental site and crop

The experiment was conducted during Kharif 2025 at the Agronomy Research Farm, College of Agriculture, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Ratnagiri, Maharashtra, India. Rice (*Oryza sativa* L.) cv. Ratnagiri-8 was transplanted on 31 July 2025 at a spacing of 20 × 15 cm. Standard agronomic practices recommended for Kharif rice in the region were followed

throughout crop growth.

Experimental design and treatments

The experiment was laid out in a randomized block design with five treatments and four replications, giving 20 experimental plots. The target pest was rice blue beetle, *L. pygmaea* and profenophos 50% EC was used as the test insecticide. Three UAV treatments represented low, medium and high- concentration spray regimes, a conventional knapsack treatment represented the manual-spraying comparison, and an untreated control received no insecticide (Table 1).

UAV and conventional application

The UAV treatments were applied using an agricultural hexacopter equipped with centrifugal nozzles. The operational settings were selected following the preceding standardization experiment. Profenophos 50% EC was applied at 3000, 4000 and 5000 mL formulation ha⁻¹ in the low-, medium- and high-concentration treatments, respectively, with a reported spray-fluid volume of 30 L ha⁻¹. The conventional treatment was applied using a knapsack sprayer at 500 mL formulation ha⁻¹ with a reported spray-fluid volume of 500 L ha⁻¹. The untreated control received no insecticide. Treatment descriptions and formulation application rates are given in Table 1. The codes 6X, 8X and 10X denote multiples of the knapsack formulation application rate per hectare; they are not multiples of spray-solution concentration.

Spraying was initiated when pest infestation reached the economic threshold level. Applications were conducted between 06:00 A.M. and 09:00 A.M. under calm weather conditions, with wind speed below 5 km h⁻¹.

Assessment of pest infestation

Observations were recorded on 10 randomly selected rice hills per plot in each replication. A pretreatment observation was recorded one day before spraying, followed by post-treatment observations at 1, 3, 5, 7, 10 and 14 days after spraying (DAS). For each sampled hill, the total number of leaves and the number of leaves showing rice blue beetle infestation were recorded. Percentage infestation was calculated as:

Infestation (%) = (number of infested leaves / total number of leaves examined) × 100.

Reduction in infestation over control

Treatment efficacy relative to the untreated control was expressed as percentage reduction in infestation over control:

Reduction (%) = [(infestation in untreated control –

Table 1 : Treatments evaluated against rice blue beetle using profenophos 50% EC.

Code	Application regime	Rate multiple ¹	Formulation rate (mL ha ⁻¹)	Reported spray fluid (L ha ⁻¹)
T ₁	UAV low concentration	6X	3000	30
T ₂	UAV medium concentration	8X	4000	30
T ₃	UAV high concentration	10X	5000	30
T ₄	Knapsack comparison	1X	500	500
T ₅	Untreated control	-	-	-

¹Multiples refer to formulation application rate per hectare relative to the 500 mL ha⁻¹ knapsack treatment. The low-, medium- and high-concentration descriptions are retained for the UAV treatments; 6X, 8X and 10X are not multiples of spray-solution concentration. UAV = unmanned aerial vehicle; EC = emulsifiable concentrate.

Table 2 : Mean rice blue beetle infestation (%) following profenophos treatments and reduction over the untreated control at 14 days after spraying.

Treatment	Pre-count (%)	1 DAS	3 DAS	5 DAS	7 DAS	10 DAS	14 DAS	Reduction (%)
T ₁	11.06 (19.43)	8.26 (16.70)	5.64 (13.73)	3.44 (10.69)	2.31 (8.75)	1.75 (7.61)	1.43 (6.87)	92.43
T ₂	11.13 (19.49)	7.70 (16.11)	4.90 (12.79)	2.85 (9.72)	1.84 (7.78)	1.34 (6.64)	1.16 (6.18)	93.86
T ₃	11.11 (19.47)	7.15 (15.51)	4.20 (11.82)	2.35 (8.80)	1.46 (6.92)	0.94 (5.55)	0.86 (5.32)	95.45
T ₄	11.17 (19.53)	9.70 (18.14)	8.14 (16.57)	6.66 (14.96)	5.86 (14.01)	5.28 (13.29)	4.95 (12.86)	73.81
T ₅	11.19 (19.54)	11.73 (20.03)	12.60 (20.79)	13.90 (21.89)	15.26 (23.00)	17.11 (24.43)	18.90 (25.77)	-
SEm(±)	0.06	0.06	0.07	0.16	0.12	0.14	0.08	
CD (P=0.05)	NS	0.18	0.21	0.48	0.37	0.44	0.24	

T₁-T₅ are defined in Table 1. Values are means of four replications; parenthetical values are the reported arcsine-transformed means. SEm = standard error of a treatment mean; CD = critical difference at P = 0.05; NS = non-significant; DAS = days after spraying. Pretreatment observations were taken one day before spraying. Reduction was calculated from displayed 14-DAS means and rounded to two decimal places.

infestation in treatment) / infestation in untreated control] × 100.

Reduction values were calculated from the displayed treatment and untreated-control means at 14 DAS and rounded to two decimal places. Thus, the reduction calculated from 0.86% and 18.90% infestation was 95.45%.

Phytotoxicity observations

Rice plants were visually examined after application for possible phytotoxic effects. The symptoms considered were yellowing, leaf burn, wilting, necrosis and stunting. Particular attention was given to the persistence or recovery of any symptoms observed after spraying.

Statistical analysis

Percentage infestation data were subjected to an

arcsine-square-root transformation [$\arcsin\sqrt{(p/100)}$, where p is percentage infestation] before analysis of variance appropriate for a randomized block design. Treatment means were compared using the critical difference at the 5% probability level. Table 2 presents untransformed percentage means with the reported transformed values in parentheses, together with standard errors of treatment means and critical differences. Pretreatment differences were reported as non-significant at P = 0.05.

Results

Pretreatment pest infestation

Rice blue beetle infestation before spraying was statistically uniform among treatments. Pretreatment infestation ranged narrowly from 11.06% to 11.19%,

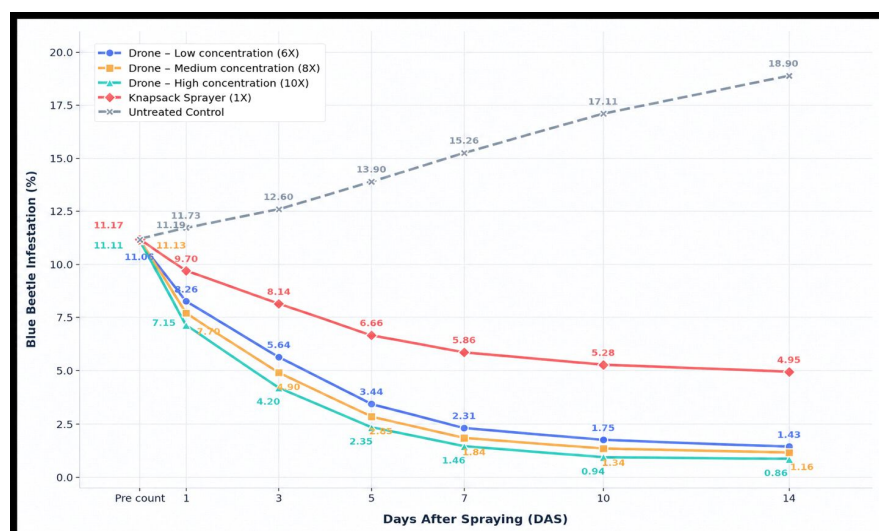


Fig. 1 : Temporal change in rice blue beetle, *Leptispa pygmaea* Baly, infestation following three low-volume UAV Profenophos 50% EC Concentration regimes, conventional knapsack application and untreated control before spraying and at 1, 3, 5, 7, 10 and 14 days after spraying. Points represent treatment means (four replications).

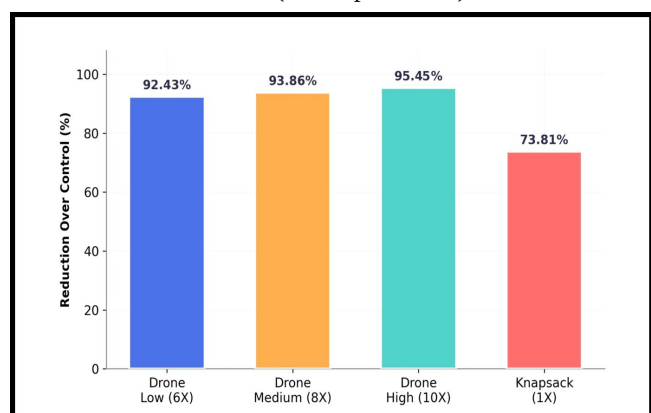


Fig. 2 : Reduction in rice blue beetle, *Leptispa pygmaea* Baly, infestation over the untreated control at 14 days after spraying.

indicating comparable pest pressure before the application treatments were imposed.

Temporal response of rice blue beetle infestation

Clear treatment differences developed after spraying and remained significant through 14 DAS (Table 2). Mean infestation declined progressively in all insecticide treatments, whereas it increased continuously in the untreated control.

The high-concentration UAV treatment (5000 mL ha⁻¹ in 30 L ha⁻¹ spray fluid) produced the lowest infestation at every post-treatment observation. Infestation declined from 7.15% at 1 DAS to 4.20% at 3 DAS, 2.35% at 5 DAS, 1.46% at 7 DAS, 0.94% at 10 DAS and 0.86% at 14 DAS.

The medium-concentration UAV treatment (4000 mL

ha⁻¹) ranked second throughout the observation period, with infestation declining from 7.70% at 1 DAS to 1.16% at 14 DAS. The low-concentration UAV treatment (3000 mL ha⁻¹) followed the same temporal pattern, declining from 8.26% to 1.43%.

Conventional knapsack application also suppressed rice blue beetle, but produced a slower and smaller decline, from 9.70% infestation at 1 DAS to 4.95% at 14 DAS. In contrast, untreated plots increased from 11.73% at 1 DAS to 18.90% at 14 DAS (Fig. 1).

Concentration response pattern under UAV application

Within the three UAV treatments, a consistent concentration-response relationship was observed. At every post-treatment interval, infestation was lowest at 5000 mL ha⁻¹, intermediate at 4000 mL ha⁻¹ and highest at 3000 mL ha⁻¹. The differences were most evident during the later observation period: at 14 DAS, infestation was 0.86%, 1.16% and 1.43% under the 5000, 4000 and 3000 mL ha⁻¹ UAV treatments, respectively.

Reduction in infestation over untreated control

At 14 DAS, the highest reduction in infestation over the untreated control was recorded by the 5000 mL ha⁻¹ UAV treatment (95.45%), followed by the 4000 mL ha⁻¹ (93.86%) and 3000 mL ha⁻¹ (92.43%) UAV treatments. The conventional knapsack treatment produced a 73.81% reduction over control (Table 2 and Fig. 2).

All three UAV treatment regimes produced substantial reductions in infestation. However, the UAV treatments received 6, 8 and 10 times the formulation application rate per hectare of the knapsack treatment. Their higher percentage reductions therefore cannot be interpreted as an unbiased comparison of application method alone.

Phytotoxicity

Slight, temporary leaf yellowing was observed during the first 2-3 days after spraying, particularly under the highest UAV concentration. The symptoms were transient: affected plants recovered within 4-5 days and leaves regained their normal green appearance. No persistent leaf burn, wilting, necrosis or stunting was observed thereafter. Thus, no lasting visual phytotoxicity was recorded under the experimental conditions. The qualitative observations are summarized in Table 3.

Table 3 : Qualitative visual phytotoxicity observations following profenophos 50% EC application.

Observation	Result
Yellowing	Slight and temporary; most evident at 5000 mL ha ⁻¹ during 2-3 DAS
Recovery	Leaves regained normal green appearance within 4-5 days
Leaf burn, wilting, necrosis and stunting	No persistent symptoms observed

These observations were qualitative; numerical phytotoxicity scores and statistical comparisons were not reported. DAS = days after spraying.

Discussion

Profenophos provided strong suppression of rice blue beetle

The progressive decline in infestation across all insecticide treatments confirms that profenophos 50% EC was biologically active against rice blue beetle under the field conditions of this study. The most direct comparison is the work of Japur *et al.* (2012), who evaluated the same insecticide against *L. pygmaea* and reported profenophos 50% EC at 2 mL L⁻¹ as the most effective insecticidal treatment, with 65.83% reduction in leaf damage over the untreated control. Although application conditions differed, that study supports the species-specific susceptibility of *L. pygmaea* to profenophos.

Hurali *et al.* (2020) evaluated profenophos 50% EC at 800, 1000 and 1200 mL ha⁻¹ against lepidopteran and sucking pests of rice and reported particularly strong activity against green leafhopper at the higher application rate. This provides supporting evidence for rate-related variation in biological efficacy, although the application rates in the present UAV treatments were substantially greater.

Low-volume UAV treatment produced rapid and sustained suppression

All three UAV treatment regimes reduced infestation rapidly after application and maintained low infestation through 14 DAS. This agrees with the broader literature showing that UAV pesticide delivery can provide effective pest suppression in paddy rice when spray conditions are suitable. Qin *et al.* (2016) reported high control efficacy against planthoppers following UAV insecticide application. Huang *et al.* (2023) likewise linked suitable UAV application parameters with more than 93% planthopper control and Wongsuk *et al.* (2024) demonstrated that UAV atomization, configuration and flight velocity influenced pest-control efficacy in rice.

Indian field evidence is also relevant. Sambaiah *et al.* (2022) demonstrated practical UAV application against rice leaf folder, while Ragiman *et al.* (2024) reported effective drone-assisted management of multiple rice pests and diseases. Naveen *et al.* (2025) specifically compared drone and knapsack application of profenophos 50% EC in paddy and reported greater reduction of leaf-folder damage under drone application. Collectively, these studies support the practical potential of UAV pesticide delivery in rice.

Interpretation of differences among application regimes

The numerical superiority of the UAV treatments over the knapsack treatment must be interpreted with reference to the treatment structure. The UAV treatments received 3000, 4000 and 5000 mL formulation ha⁻¹, compared with 500 mL ha⁻¹ in the conventional treatment. Application platform, formulation application rate and reported spray-fluid volume therefore differed simultaneously. The experiment compares complete treatment regimes and does not isolate the independent effect of the spraying platform.

The 95.45% reduction under the highest-concentration UAV treatment demonstrates strong suppression under that particular regime. It does not establish that UAV application alone caused the difference from the 73.81% reduction under knapsack spraying. A platform comparison would require an equal active-ingredient application rate per hectare, with spray-fluid volume controlled or varied as a separate experimental factor.

Within the UAV treatments, the reported spray-fluid volume was constant while the amount of formulation increased. The observed concentration-response pattern therefore also represents a response to increasing formulation application rate. Future experiments should explicitly distinguish formulation rate, spray-fluid volume and application platform. Chen *et al.* (2020b) showed that droplet size affected deposition and drift in UAV spraying, while Chen *et al.* (2022) emphasized the need for dedicated drift assessment. Direct off-target drift measurements were not available for the present biological-efficacy comparison.

Spray-fluid volume contrast and practical interpretation

The UAV treatments used 30 L ha⁻¹ spray-fluid volume compared with 500 L ha⁻¹ for the knapsack treatment. This represents a 94% reduction in the reported spray-fluid volume. Low-volume spraying is one of the main operational advantages of agricultural UAVs,

especially in flooded rice where water transport and operator movement can constrain timely pesticide application. However, concentrating a pesticide into a much smaller carrier volume can change deposition, droplet evaporation, leaf retention and local exposure on the crop surface; biological efficacy must therefore be evaluated together with crop safety and residue considerations. Jeevan *et al.* (2023) demonstrated that spray volume influenced deposition characteristics in transplanted rice during UAV herbicide application; this is relevant to spray delivery but does not directly establish insecticidal efficacy against rice blue beetle.

Crop safety observations

The transient yellowing observed for 2-3 days, particularly at the highest concentration, indicates that the concentrated UAV treatment was associated with a temporary visible response on the crop. Recovery within 4-5 days and the absence of persistent leaf burn, wilting, necrosis or stunting suggest that no lasting visual phytotoxicity developed under the conditions of this experiment.

Other UAV studies in rice have also reported acceptable crop safety under tested pesticide regimes. Sambaiah *et al.* (2022) observed no visible phytotoxic symptoms following UAV application of flubendiamide, Paul *et al.* (2024) reported crop safety following UAV herbicide application in direct-seeded rice, and Kavya *et al.* (2025) found no phytotoxicity from drone-applied flupyrimin even at the highest application rate tested. Nevertheless, visual recovery alone does not establish toxicological or residue safety, particularly at the high formulation application rates evaluated in the present study.

Practical implications and limitations

The study demonstrates that low-volume UAV application can deliver strong field suppression of rice blue beetle and that increasing the profenophos formulation application rate from 3000 to 5000 mL ha⁻¹ produced progressively lower infestation. The 5000 mL ha⁻¹ UAV treatment was the most effective treatment biologically, reaching 0.86% infestation and 95.45% reduction over control at 14 DAS.

However, the study was conducted at a single location and during one Kharif season. The UAV treatments used insecticide application rates substantially greater than the conventional comparison, and no residue, environmental-exposure, yield or economic data were generated within this objective. Accordingly, the highest concentration treatment should not be interpreted as a field recommendation solely from the present experiment.

Multi-location and multi-season studies using equal-rate UAV-versus-knapsack comparisons, residue analysis, environmental-risk assessment and economic evaluation are needed before practical application-rate recommendations are proposed.

Conclusion

Low-volume UAV application of profenophos 50% EC produced strong and sustained suppression of rice blue beetle under the experimental conditions. Among the UAV concentration regimes, increasing formulation application rate from 3000 to 5000 mL ha⁻¹ progressively reduced pest infestation. At 14 DAS, infestation was 1.43%, 1.16% and 0.86% under the 3000, 4000 and 5000 mL ha⁻¹ UAV treatments, respectively, corresponding to 92.43%, 93.86% and 95.45% reduction over the untreated control. Conventional knapsack application at 500 mL ha⁻¹ reduced infestation to 4.95%, equivalent to 73.81% reduction over control.

Slight, temporary yellowing was observed, particularly under the highest-concentration UAV treatment, and plants recovered within 4-5 days without persistent visible phytotoxic symptoms. The experiment therefore demonstrates a clear concentration-dependent biological response under low-volume UAV application. Because the UAV and knapsack treatments differed in formulation application rate as well as spray-fluid volume, the superior performance of the UAV regimes reflects the combined effects of application rate and delivery conditions and cannot be attributed to application platform alone. Further comparisons at equal active-ingredient application rates and residue and environmental assessments are essential before translating these findings into a recommendation.

Acknowledgement

The authors acknowledge the Department of Agricultural Entomology, Department of Agronomy and Department of Agricultural Engineering, College of Agriculture, Dr. Balasaheb Sawant Konkan Krishi Vidyapeeth, Dapoli, Maharashtra, India, for providing the experimental field, facilities and technical support required for this research. This research received no specific external funding.

Author contributions

Rohit Shashikant Mane: Investigation, data curation, formal analysis, visualization and writing the original draft. Sakham D. Desai: supervision and manuscript review and editing. Vijaykumar S. Desai: Methodology, resources, Conceptualization and manuscript review and editing. Sachin V. Pathak: Technical guidance, methodology, and

manuscript review and editing. Vijay G. More: Methodology and validation. Audumbar V. Asawale, Neha A. Zende and Tanaya R. Dalvi: Data collection, Manuscript review and editing.

Data availability

The data supporting the findings of this study are available from the corresponding author upon reasonable request.

Conflict of interest

The authors declare no conflict of interest relevant to this study.

Declaration of AI assistance

ChatGPT (OpenAI) was used to assist with manuscript organization, language revision, reference-format checks and consistency checks against the supplied thesis. The experimental observations originated from the research records and from actual field observation.

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