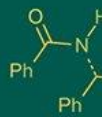


International Journal of Advanced Biochemistry Research



ISSN Print: 2617-4693
ISSN Online: 2617-4707
NAAS Rating (2026): 5.29
IJABR 2026; SP-10(6): 473-478
www.biochemjournal.com
Received: 19-03-2026
Accepted: 21-04-2026

Jarpula Vinay
Rice Research Unit, ARI,
PJTAU, Rajendranagar,
Hyderabad, Telangana, India

Kiran Babu Talluri
Rice Research Unit, ARI,
PJTAU, Rajendranagar,
Hyderabad, Telangana, India

T Rajeshwar Reddy
TRVK, Vikarabad, Telangana,
India

N Rama Gopala Varma
Programme Coordinator,
KVK, Adilabad, Telangana,
India

Assessment of physical compatibility of newer pesticide–adjuvant combinations for UAVs based spraying

Jarpula Vinay, Kiran Babu Talluri, T Rajeshwar Reddy and N Rama Gopala Varma

DOI: <https://www.doi.org/10.33545/26174693.2026.v10.i6Sf.8637>

Abstract

Rice remained a staple food crop for over one billion people worldwide. Productivity was constrained by many biotic and abiotic stresses chemical control was widely used. UAV-based spraying reduced labour, time and exposure. Adjuvants improved the efficacy, but compatibility issues of pesticides and adjuvants necessitated jar tests for tank mixing of pesticides in crop protection using drones. In order to do this, researchers investigated the physical compatibility of each five insecticides, fungicides, mixed with three adjuvants, at drone spraying concentrations using a jar compatibility test. Among the 64 combinations tested, 30 combinations exhibited foaming and sedimentation under UAVs spray concentrations, while 34 combinations remained physically compatible with negligible instability. Foaming in incompatible mixtures ranged from 0.5 to 5 ml and sedimentation ranged from 0.5 to 2 ml after 60 min of observation. The combinations of Isocycloseram 18.1% SC, Spinetoram 11.7% SC, and Chlorantraniliprole 18.5% SC with selected fungicides were physically compatible, showing negligible foaming and sedimentation under drone spraying conditions. In contrast, incompatible combinations exhibited visible foaming and sedimentation, while Novaluron 5.25% + Emamectin benzoate 0.9% SC with Stikker Plus adjuvant showed maximum stability. The goal of this study showed that, excellent stability without foaming and sedimentation are required for safe use of tank mix application of pesticides with adjuvants using drones in rice.

Keywords: *Oryza sativa*, drone spraying, pesticides, adjuvants and pesticide compatibility

1. Introduction

Paddy (*Oryza sativa* L.) is cultivated globally being one of the most important cereal crops worldwide. It is cultivated in more than 100 countries on every continent, except, for Antarctica, although 91 per cent of the world's rice is grown and consumed in Asia. USDA's global rice production in 2025-26 is projects lower supplies, smaller consumption, reduced trade and higher ending stocks. World 2025-26 consumption is lowered 0.8 million tons to 541.0 million, mostly on smaller consumption estimates for several African countries. Global 2025-26 trade is decreased 1.3 million tons to 62.0 million, largely on a slower-than-expected pace of exports from India. Paddy acreage increased by 0.6% to 45 lakh hectares from 44.73 lakh hectares. Rice production was projected at 1406.48 lakh tonnes. Uttar Pradesh remained the largest producer, followed by Telangana and Punjab, with significant contributions from West Bengal, Madhya Pradesh, Andhra Pradesh, Odisha, and Chattisgarh (Anonymous, 2026) ^[1].

Rice cultivation is highly affected by major insect pests and diseases such as stem borer, leaf folder, brown planthopper, Bacterial leaf blight, rice blast, sheath blight, sheath rot and grain discoloration, which considerably reduce yield and grain quality (Savary *et al.*, 2019) ^[15]. Effective management of these problems mainly depends on timely pesticide application (Prasad and Eizenga, 2008) ^[10]. Traditionally, pesticides are applied using knapsack sprayers, power sprayers and tractor-mounted sprayers. However, conventional spraying has challenges are like uneven spray coverage, poor canopy penetration, excessive pesticide wastage, spray drift, and high labour requirements (Lan and Chen, 2018) ^[8]. In rice ecosystems, spraying becomes more difficult during later crop stages because dense canopy and flooded field conditions obstruct the penetration of spray droplets into lower plant regions where diseases like sheath blight usually initiate.

Corresponding Author:
Jarpula Vinay
Rice Research Unit, ARI,
PJTAU, Rajendranagar,
Hyderabad, Telangana, India

In addition, manual spraying exposes workers directly to hazardous chemicals and increases environmental contamination through runoff and drift (Zhang *et al.*, 2011)^[20]. These limitations created the need for advanced and precision-based spraying technologies such as Unmanned Aerial Vehicles (UAVs) for efficient crop protection in rice. Unmanned Aerial Vehicles (UAVs) are commonly called agricultural drones emerged as an important precision agriculture technology for pesticide application to the farmers doorstep. UAVs can operate autonomously or through remote control and offer several advantages over conventional spraying methods including rapid spraying, uniform droplet distribution, reduced labour dependency, low water requirement, timely application and improved safety to applicators (Chen *et al.*, 2020)^[13]. Drone spraying also improves canopy penetration through rotor-induced downwash airflow, enabling better deposition of droplets on lower portions of rice plants. Studies reported that UAV spraying improves spray efficiency, reduces pesticide losses, and enhances pest and disease control even under difficult field conditions (Wang *et al.*, 2019; Hu *et al.*, 2024)^[19, 7]. Recognizing the potential benefits of drone technology in agriculture, the Govt of India has actively promoted the adoption of agricultural drones through initiatives such as the Sub-Mission on Agricultural Mechanization (SMAM), and the Namo Drone Didi Scheme to encourage precision farming and modern crop management practices. Furthermore, Professor Jayashankar Telangana Agricultural University has developed Standard Operating Procedures (SOPs) for UAV-based pesticide application in major field crops including rice (Varma *et al.*, 2022)^[18].

Adjuvants are supplementary substances added to pesticide spray solutions to improve spray performance and pesticide efficiency (Bao *et al.*, 2022)^[2]. They include surfactants, spreaders, stickers, compatibility agents, anti-foaming agents and drift-control compounds. In UAV spraying systems, adjuvants play a major role in reducing surface tension, improving droplet spreading wettability, minimizing evaporation, reducing spray drift, and increasing deposition on rice leaves. Several studies demonstrated that tank-mix adjuvants significantly improve spray characteristics and biological efficacy of pesticides applied through drones (Ma *et al.*, 2022)^[9]. Research findings indicated that the addition of suitable adjuvants enhanced canopy coverage, droplet retention and pesticide utilization efficiency while reducing pesticide usage by nearly 20 per cent. Different adjuvants such as organosilicon surfactants, lecithin-based compounds, mineral oils, and plant essential oils were found effective in improving spray deposition and pest control efficiency in rice and other crops under UAV spraying conditions (He *et al.*, 2021)^[6].

Tank-mixing of insecticides and fungicides is increasingly practiced by farmers to reduce spraying frequency, labour costs and operational expenses while improving insect-pest and disease management efficiency. However, improper mixing of pesticides at high concentrations may lead to incompatibility problems such as sedimentation, foaming, flocculation, precipitation, nozzle blockage, uneven spray distribution, reduced control efficacy and phytotoxicity (Rajasekar and Mallapur, 2017)^[12]. Therefore, evaluating the physical compatibility of pesticides with adjuvants under UAV spray concentrations is essential before field application.

The present experiment focuses on studying the compatibility of newer fungicides and insecticides with adjuvants such as Silwet Gold, SPREAD-X 180 and Stikker Plus under drone spraying concentration in rice. Since, very limited information is available under Indian conditions regarding pesticide-adjuvant combinations applied through UAVs systems, this investigation represents a pioneering and systematic effort toward the development of efficient, sustainable and precision-driven UAVs based pesticide application strategies for enhanced rice crop protection.

2. Materials and Methods

The physical compatibility of eight individual pesticides comprising of each four insecticides, fungicides and three adjuvants as presented in Table 1 along with their sixty-four (64) possible combinations, were evaluated under laboratory conditions through a jar compatibility test (14). The compatibility studies were carried out using pesticide concentrations recommended for drone (UAVs) sprayer. The pesticides and adjuvants selected for the investigation were chosen based on their broad-spectrum effectiveness, economic feasibility and commercial availability in the market.

2.1 The pesticides and adjuvants

The four insecticides studied are Isocycloseram 18.1% SC, Spinetoram 11.7% SC, Chlorantraniliprole 18.5% SC, and Novaluron 5.25% + Emamectin benzoate 0.9% SC. The fungicides evaluated under this study are Azoxystrobin 5.1% + Tebuconazole 9.1% + Prochloraz 18.2% EC, Validamycin 5% + Tebuconazole 15% SC, Mefentrifluconazole 200 + Fluxapyroxad 200 g/l SC and Azoxystrobin 18.2% + Difenconazole 11.4% SC. whereas adjuvants, namely Silwet Gold, SPREAD-X 180 and Stikker Plus, were included in the compatibility studies.

2.2 Preparation of drone spray concentrations

Drone spray concentrations were calculated by maintaining the recommended active ingredient dose per hectare while adjusting the pesticide concentration according to the lower spray volume used in UAVs spraying. A spray volume of 40 L ha⁻¹ was adopted for drone application (18). The recommended pesticide dose per hectare was recalculated to obtain the required concentration per litre of spray solution while ensuring the total active ingredient applied per hectare remained equivalent to the conventional recommended dose. All pesticide combinations were tested along with adjuvants at their respective drone spray concentrations. Silwet Gold was used at 0.33 mL L⁻¹, whereas SPREAD-X 180 and Stikker Plus were used at 0.5 mL L⁻¹ of water for evaluating their compatibility with pesticide mixtures under UAV spraying conditions.

2.3 Procedure for jar compatibility test

Water collected from the open well at the experimental site was used for preparation of all pesticide mixtures. A measured quantity of water was taken in a one-litre glass jar into which one insecticide and one fungicide were added at their respective drone spray doses. The pesticides were mixed according to the WALES mixing sequence suggested by (Suganthi *et al.*, 2010)^[16] wherein wet table powders (WP) and water dispersible granules (WDG) were added first, followed by suspension concentrates (SC) and flowables, and finally emulsifiable concentrates (EC) and

soluble concentrates (SL). After addition of the pesticides, the adjuvants will be added, the volume was made up to one litre with water and the mixture was shaken thoroughly to ensure uniform mixing.

From the prepared spray mixture, 100 mL of solution was transferred into a 100 mL calibrated knobbed measuring cylinder and kept undisturbed under laboratory conditions for 60 min. Observations on physical compatibility parameters such as foaming, sedimentation was recorded after 30 and 60 min of observation period. The compatibility of pesticide mixtures was assessed based on the absence or presence of these physical abnormalities.

2.4 pH measurement

The pH of individual insecticides, fungicides, adjuvants, and their combinations at drone spraying concentrations was measured using a digital pH meter. The recorded pH values were classified into different categories, such as acidic, neutral and alkaline according to the classification proposed.

3. Results and Discussion

3.1 The pesticides and adjuvants

The results of the present investigation on the physical compatibility of insecticide–fungicide combinations with adjuvants under UAV spraying conditions revealed that most of the tested combinations were physically stable and suitable for drone application in rice. In the jar compatibility test, the majority of the pesticide mixtures without adjuvants showed no visible foaming or sedimentation, indicating good compatibility under drone spraying concentration. Among the sixteen combinations tested, combinations involving Isocycloseram 18.1% SC + (Mefentrifluconazole 200 + Fluxapyroxad 200 g/l SC) and Novaluron + Emamectin benzoate + (Mefentrifluconazole 200 + Fluxapyroxad 200 g/l SC) recorded the slight sedimentation, whereas Spinetoram 11.7% SC combinations showed minor foaming and sedimentation (Table 2). The present findings were in agreement with the results reported by Raju *et al.*, 2018 reported that chlorantraniliprole exhibited physical compatibility with the fungicides tricyclazole, hexaconazole and propiconazole, as no signs of sedimentation or foaming were observed in the tested mixtures at Taiwan sprayer application concentration. A few pesticide mixtures produced foaming under concentrated drone spray volumes, while most combinations remained physically stable (Ragiman *et al.*, 2023) [11]. Similarly, (Georgia, 2019) [4] reported that the combinations of chlorantraniliprole with azoxystrobin and hexaconazole were both physically and chemically compatible. Further, (Goud *et al.*, 2010) [5] stated that propiconazole when combined with insecticides such as indoxacarb and novaluron showed no foaming, while sedimentation values of 1.8 ml and nil, respectively, were recorded, which were within the permissible ISI limit of 2 ml per 100 ml.

The addition of adjuvants influenced the compatibility behaviour of the spray mixtures. Among the adjuvants tested, Silwet Gold produced comparatively higher foaming, especially in combinations involving Mefentrifluconazole 200 + Fluxapyroxad 200 g/l SC, where foaming reached up to 5 ml. Spread-X 180 also caused moderate foaming and slight sedimentation in some combinations, while Stikker Plus exhibited comparatively better physical stability with very low foaming and sedimentation. However, severe precipitation or separation was not observed in any

treatment. The increased foaming observed with Silwet Gold might be due to its surfactant properties under concentrated UAV spray conditions (Table 2 and Fig 1).

3.2 pH Measurement

The pH studies revealed that the individual pesticides, adjuvants and their combinations remained within neutral to slightly alkaline range. The pH of individual chemicals varied from 7.16 to 8.40 Fig 2 while the pH of combinations ranged between 6.48 and 7.86. The combinations involving Validamycin 5% + Tebuconazole 15% SC maintained near-neutral pH, whereas combinations containing Mefentrifluconazole 200 + Fluxapyroxad 200 g/l SC showed slightly alkaline nature. Spread-X 180 exhibited comparatively higher pH due to its alkaline nature, while Silwet Gold and Stikker Plus maintained relatively stable pH conditions. Importantly, none of the combinations showed extreme acidic or highly alkaline conditions, which indicates that favourable conditions for pesticide stability and bio-efficacy Table 2. Similar findings were reported by (Ragiman *et al.*, 2023) [11] who stated that certain pesticide mixtures at drone spraying concentration showed increased foaming due to higher chemical concentration in low-volume applications. pH analysis of pesticide formulations and their combinations used in rice crop protection revealed that most treatments maintained a nearly neutral reaction, whereas cartap hydrochloride 50% SP exhibited comparatively higher acidity along with slight pH variations in a few pesticide combinations (Supriya *et al.*, 2024) [17]. The absence of extreme pH conditions also corresponded with minimal sedimentation observed during jar compatibility testing, suggesting good chemical stability of the spray mixtures applied through drones. The present findings are also in agreement with (Rajasekar and Mallapur, 2017) [12] who reported that physical compatibility of pesticide mixtures is closely associated with maintaining favourable pH conditions.

Overall, the results demonstrated that most insecticide–fungicide combinations tested in the present study were physically and chemically compatible under UAV spraying conditions. The compatible mixtures exhibited good stability with negligible foaming and sedimentation and maintained favourable pH levels suitable for drone-based low-volume spraying. The study further indicated that proper selection of adjuvants is essential to improve spray uniformity and compatibility under UAV applications. These findings support the safe and effective use of compatible pesticide mixtures for precision crop protection in rice cultivation.

4. Conclusion

The study concluded that most insecticide-fungicide combinations tested under UAV spraying were physically and chemically compatible. Jar tests showed negligible foaming and sedimentation, indicating suitability for low-volume drone spraying tank mixing of pesticide with adjuvants. The pH of pesticides, adjuvants, and mixtures remained neutral to slightly alkaline, supporting stability. Among adjuvants, Stikker Plus showed better compatibility, while Silwet Gold produced relatively higher foaming. Overall, selected combinations were safely and effectively used through UAVs for precise and sustainable insect pest and disease management in rice.

5. Future Scope

The findings of the present investigation and earlier studies clearly demonstrated that the incorporation of suitable tank-mix adjuvants in UAV-based pesticide application systems can considerably enhance spray retention, wetting, spreading behaviour, and deposition efficiency on plant surfaces, thereby improving pesticide utilization efficiency even at reduced pesticide dosages. The improved physicochemical characteristics achieved through adjuvant incorporation indicated the possibility of maintaining effective pest and disease management while reducing the quantity of pesticide applied, which is highly important for sustainable agriculture and environmental safety. Future research should therefore focus on evaluating the extent of pesticide dosage reduction possible under different UAV spraying conditions without compromising biological efficacy. Detailed investigations on optimized adjuvant-pesticide combinations, spray volume, droplet spectrum, nozzle type, and flight parameters are essential to achieve maximum target coverage with minimum chemical input. In addition, large-scale field studies under diverse agro-climatic conditions are necessary to assess spray deposition, drift reduction, phytotoxicity, residue dynamics and

economic feasibility associated with reduced-dose UAV spraying. The adoption of efficient adjuvant-assisted low-dose pesticide application strategies can significantly reduce chemical wastage, production costs, labour dependency and environmental contamination while promoting precision, sustainability and eco-friendly crop protection practices.

6. Acknowledgement

The authors are highly thankful to Professor Jayashankar Telangana Agricultural University and the Agricultural Research Institute, Rice Research Unit for providing the necessary infrastructural facilities, technical support, and financial assistance for conducting this research work.

7. Disclaimer (Artificial intelligence)

Author(s) hereby declares 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.

8. Competing Interests

The authors declare that they have no competing interests.



Fig 1: Physical compatibility of pesticide–adjuvant combinations showing no foaming, foaming and sedimentation under UAV spray concentration

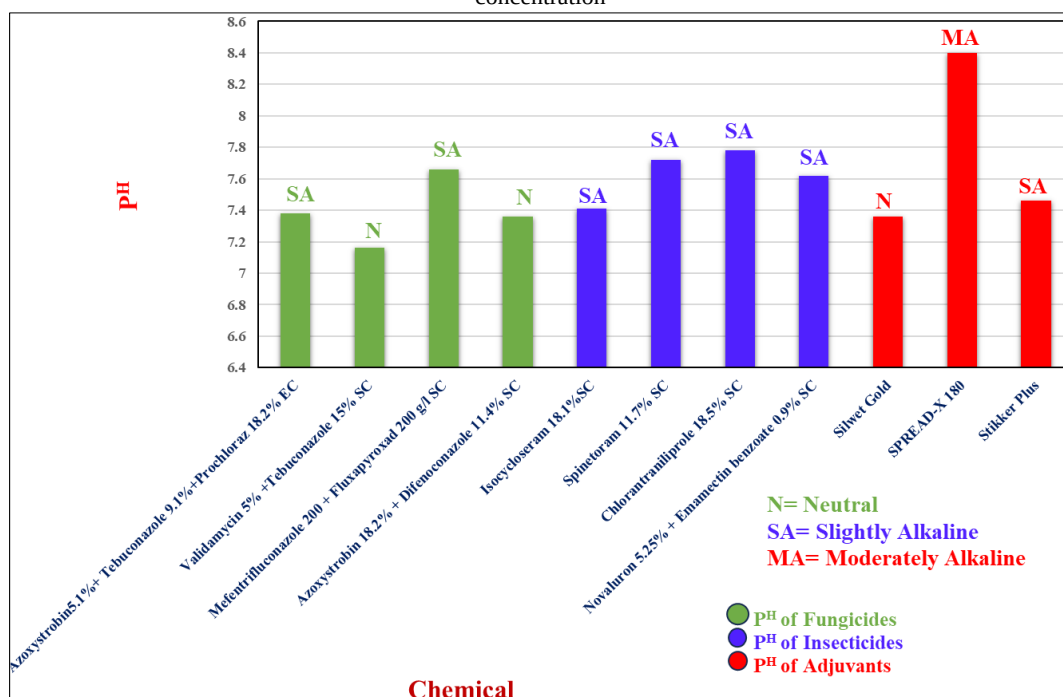


Fig 2: Details of pH on pesticides and adjuvants

Table 1: Details of insecticides, fungicides and adjuvants tested for p^H physical compatibility

S.No.	Pesticides	Trade name	Recommended dose (g or ml ha ⁻¹)	Drone spraying dose (g or ml lit ⁻¹ of water)	Source of supply
Insecticides					
1	Isocycloseram 18.1%SC	Incipio	300 ml	7.5 ml	M/s. Syngenta India Ltd., Mumbai
2	Spinetoram 11.7% SC	Delegate	250 ml	6.25 ml	M/s. Dow Agro Sciences India Pvt. Ltd., Mumbai
3	Chlorantraniliprole 18.5% SC	Coragen	150 ml	3.75 ml	M/s. FMC India Pvt. Ltd., Ahmedabad
4	Novaluron 5.25% + Emamectin benzoate 0.9% SC	Barazide	1500 ml	37.5 ml	M/s. Adama India Pvt. Ltd., Hyderabad.
Fungicides					
5	Azoxystrobin 5.1%+ Tebuconazole 9.1% +Prochloraz 18.2% EC	Almagor	1750 ml	43.75 ml	M/s. Adama India Pvt. Ltd., Hyderabad
6	Validamycin 5% +Tebuconazole 15% SC	Ormie	1000 ml	25 ml	M/s. Sumitomo Chemical India Ltd., Hyderabad.
7	Mefentrifluconazole 200 + Fluxapyroxad 200 g/l SC	Mibelya	300 ml	7.5 ml	M/s. BASF India Limited., New Delhi
8	Azoxystrobin 18.2% + Difenconazole 11.4% SC	Amistar Top	500 ml	12.5 ml	M/s. Syngenta India Ltd., Mumbai
Adjuvants					
9	Non-ionic organosilicone surfactant	Silwet Gold	13.2 ml	0.33 ml	M/s. UPL Limited., Mumbai.
10	Non-ionic surfactant-based adjuvant	SPREAD-X 180	20 ml	0.5 ml	M/s. Maltose Bio Innovation Private Limited., Bengaluru.
11	Silicon-based spreader	Stikker Plus	20 ml	0.5 ml	M/s. Agreo Solutions., Mumbai.

Table 2: Overall Compatibility Behaviour of Pesticide Combinations with and without adjuvants and p^H of pesticide-adjuvant combination under UAVs Spray Conditions

S. No.	Pesticide Combination	Without Adjuvant	Silwet Gold	SPREAD-X 180	Stikker Plus	p ^H Range	Nature
1.	Isocycloseram 18.1%SC +(Azoxystrobin 5.1%+ Tebuconazole 9.1%+Prochloraz 18.2% EC)	☑	☑	✗	☑	7.2–7.4	Neutral
2.	Isocycloseram 18.1%SC+(Validamycin 5% +Tebuconazole 15% SC)	☑	☑	☑	☑	6.5–6.6	Neutral
3	Isocycloseram 18.1%SC+ (Mefentrifluconazole 200 + Fluxapyroxad 200 g/l SC)	✗	✗	✗	☑	7.5–7.8	Slightly alkaline
4	Isocycloseram 18.1%SC+(Azoxystrobin 18.2% + Difenconazole 11.4% SC)	☑	✗	☑	✗	7.4–7.7	Slightly alkaline
5	Spinetoram 11.7% SC+(Azoxystrobin 5.1%+ Tebuconazole 9.1%+Prochloraz 18.2% EC)	☑	☑	✗	☑	7.4–7.6	Slightly alkaline
6	Spinetoram 11.7% SC+(Validamycin 5% +Tebuconazole 15% SC)	☑	☑	☑	☑	6.5–6.7	Neutral
7	Spinetoram 11.7% SC+(Mefentrifluconazole 200 + Fluxapyroxad 200 g/l SC)	✗	✗	✗	✗	7.5–7.9	Slightly alkaline
8	Spinetoram 11.7% SC+(Azoxystrobin 18.2% + Difenconazole 11.4% SC)	✗	✗	☑	✗	7.5–7.8	Slightly alkaline
9	Chlorantraniliprole 18.5% SC++(Azoxystrobin 5.1%+ Tebuconazole 9.1%+Prochloraz 18.2% EC)	☑	☑	✗	☑	7.2–7.4	Neutral
10	Chlorantraniliprole 18.5% SC+(Validamycin 5% +Tebuconazole 15% SC)	☑	✗	☑	✗	6.4–6.6	Neutral
11	Chlorantraniliprole 18.5% SC+(Mefentrifluconazole 200 + Fluxapyroxad 200 g/l SC)	☑	✗	✗	✗	7.5–7.8	Slightly alkaline
12	Chlorantraniliprole 18.5% SC+(Azoxystrobin 18.2% + Difenconazole 11.4% SC)	☑	✗	✗	☑	7.5–7.8	Slightly alkaline
13	Novaluron 5.25% + Emamectin benzoate 0.9%SC++(Azoxystrobin 5.1%+ Tebuconazole 9.1%+Prochloraz 18.2% EC)	☑	✗	☑	☑	7.2–7.3	Neutral
14	Novaluron 5.25% + Emamectin benzoate 0.9% SC+(Validamycin 5% +Tebuconazole 15% SC)	☑	☑	☑	✗	6.5–6.6	Neutral
15	Novaluron 5.25% + Emamectin benzoate 0.9% SC+(Mefentrifluconazole 200 + Fluxapyroxad 200 g/l SC)	✗	✗	✗	✗	7.3–7.7	Slightly alkaline
16	Novaluron 5.25% + Emamectin benzoate 0.9% SC+(Azoxystrobin 18.2% + Difenconazole 11.4% SC)	☑	✗	✗	☑	7.3–7.7	Slightly alkaline

☑ = Compatible, ✗ = Incompatible

References

- Anonymous. 2026. <https://drive.google.com/file/d/1VRc9EabL4nbxamSY-Ppj1vvBbf5Z4wQC/view>.
- Bao Z, Wu Y, Song R, Gao Y, Zhang S, Zhao K, *et al.* The simple strategy to improve pesticide bioavailability and minimize environmental risk by effective and

- ecofriendly surfactants. *Science Total Environment*. 2022;85(3):158-169.
3. Chen P, Lan Y, Huang X, Qi H, Wang G, Wang J, *et al.* Droplet deposition and control of planthoppers of different nozzles in two-stage rice with a quadrotor unmanned aerial vehicle. *Agronomy*. 2020;10(2):303.
 4. Georgia EK. Bioefficacy of fungicides and their compatibility with insecticides in managing blackgram diseases. M.Sc. (Ag.) Thesis. Acharya N G Ranga Agricultural University, Guntur. 2019.
 5. Goud RCh, Rao KSR, Rahman SJ, Prasad RD. Studies on compatibility of certain insecticides with chlorothalonil against pod borer, die-back and fruit rot in chilli. *Indian Journal of Plant Protection*. 2010;38(1):47-52.
 6. He L, Ding L, Zhang P, Li B, Mu W, Liu F. Impact of the equilibrium relationship between deposition and wettability behaviour on the high-efficiency utilization of pesticides. *Pest Management Science*. 2021;77(5):2485-2493.
 7. Hu H, Ma Y, Song X, Wang D, Ren X, Wu C, *et al.* Tank-mix adjuvants enhance pesticide efficacy by improving pH physicochemical properties and spraying characteristics for application to cotton with unmanned aerial vehicles. *ACS Omega*. 2024;9(28):31011-31025.
 8. Lan Y, Chen S. Current status and trends of plant protection UAV and its spraying technology in China. *International Journal of Precision Agricultural Aviation*. 2018;1(1):1-9.
 9. Ma Y, Ma L, Zhang Q, Huang C, Yi X, Chen X, *et al.* Cotton yield estimation based on vegetation indices and texture features derived from RGB image. *Frontiers in Plant Science*. 2022;13:925986.
 10. Prasad B, Eizenga GC. Rice sheath blight disease resistance identified in *Oryza* spp. accessions. *Plant Disease*. 2008;92(11):1503-1509.
 11. Ragiman S, Talluri KB, Varma NRG, Sagar BV, Devi GU. Assessment of Pesticide Mixtures for Unmanned Aerial Spraying in Rice: A Physical Compatibility Perspective. *International Journal of Environment and Climate Change*. 2023;13(9):2848-2858.
 12. Rajasekar B, Mallapur CP. Physical compatibility of agro-chemicals in laboratory. *Journal of Pharmacognosy and Phytochemistry*. 2017;6(3):273-275.
 13. Raju KP, Rajasekhar P, Rajan CPD, Venkateswarlu NC. Studies on the physical, chemical compatibility and phytotoxic effects of some insecticides and fungicides combinations in rice crop. *International Journal of Pure and Applied Bioscience*. 2018;6(1):292-299.
 14. Sabitha C, Dhurua S, Sreesandhya N, Suresh M. Physical compatibility and phytotoxic studies of insecticides and fungicide mixtures on rice. *Andhra Pradesh Journal of Agricultural Science*. 2020;67(3):187-193.
 15. Savary S, Willocquet L, Pethybridge SJ, Esker P, McRoberts N, Nelson A. The global burden of pathogens and pests on major food crops. *Nature Ecology and Evolution*. 2019;3(3):430-439.
 16. Suganthi M, Kuttalam S, Chandrasekaran S. Compatibility of confidence (Imidacloprid 17.8% SL) with some chemical and botanical pesticides on cotton, Bendi and Chilli. *Madras Agricultural Journal*. 2010;97(1/3):73-74.
 17. Supriya K, Varma NRG, Upendhar S, Babu TK, Lingaiah N. Evaluation of the Physical Compatibility of Biopesticides and Chemical Pesticides for Drone Application. *Journal of Scientific Research and Reports*. 2024;30(8):744-754.
 18. Varma NRG, Babu TK, Ramprasad B, Ashwini D, Reddy TR, Sudhakar C, *et al.* Autonomous Drones in Agriculture: Standard Operating Protocols for Agrochemical Application in Field Crops. Publication No. 15/TP/PJTSAU/2022. University Press, PJTSAU, Rajendranagar, Hyderabad, Telangana State, India. 2022. p.16.
 19. Wang GB, Lan YB, Qi HX, Chen PC, Hewitt A, Han YX. Field evaluation of an unmanned aerial vehicle (UAV) sprayer: Effect of spray volume on deposition and the control of pests and disease in wheat. *Pest Management Science*. 2019;75:1546-1555.
 20. Zhang X, Zhao W, Jing R, Wheeler K, Smith GA, Stallones L, *et al.* Work-related pesticide poisoning among farmers in two villages of Southern China: A cross-sectional survey. *BMC Public Health*. 2011;11:429.
 21. Zhao R, Sun Z, Bird N, Gu YC, Xu Y, Zhang ZH, *et al.* Effects of tank-mix adjuvants on physicochemical properties and dosage delivery at low dilution ratios for unmanned aerial vehicle application in paddy fields. *Pest Management Science*. 2022;78(4):1582-1593.
 22. Zhao R, Yu M, Sun Z, Li LJ, Shang HY, Xi WJ, *et al.* Using tank-mix adjuvant improves the physicochemical properties and dosage delivery to reduce the use of pesticides in unmanned aerial vehicles for plant protection in wheat. *Pest Management Science*. 2022;78(6):2512-2522.