

ASSESSING THE SUITABILITY OF PESTICIDE MIXTURES FOR UNMANNED AERIAL SPRAYING IN RICE: A PHYSICAL COMPATIBILITY PERSPECTIVE

Abstract

The use of drone spraying technology has shown great promise in overcoming the limitations of manual spraying in agriculture. However, ensuring the physical compatibility of pesticide mixtures for drone applications remains a crucial aspect. In this study, we conducted an experiment to investigate the physical compatibility of five insecticides *viz*, chlorantraniliprole 18.5% SC, tetraniliprole 200 SC, cartap hydrochloride 50% SP, flubendiamide 39.35% SC, and acephate 50% + imidacloprid 1.8% SP with five fungicides *viz*, picoxystrobin 7.5% + tricyclazole 22.5% SC, azoxystrobin 18.2% + difenoconazole 11.4% SC, tebuconazole 50% + trifloxystrobin 25% WG, picoxystrobin 7% + propiconazole 12% SC, and prochloraz 23.5% + tricyclazole 20% SE at drone and taiwan spraying concentrations by jar compatibility test. Among the 25 combinations tested only seven combinations at drone spraying concentration showed foaming ranging from 15-20 ml/l. Furthermore, none of the pesticides or their combinations shown alkaline pH. Thus, all the pesticide combinations demonstrated resistance to alkaline degradation, potentially leading to the formation of sedimentation when these pesticides are combined.

Keywords: Pesticide compatibility, drone spraying, taiwan sprayer, jar compatibility test, Compatibility issues, alkaline degradation, pesticide combinations.

Introduction

In the field of agriculture, the application of pesticides has traditionally been carried out through two methods: ground spraying and aerial spraying (Faical et al., 2017). However, ground spraying poses significant challenges, including increased pesticide exposure for operators and potential issues with spray dispersal, leading to ineffective chemical application. Operators using manual backpack sprayers are exposed to highly toxic pesticides, resulting in acute poisoning cases reported by the World Health Organization (WHO) affecting approximately 1,000,000 individuals annually. The fatality rate ranges between 0.4 to 1.9 percent due to exposure to these toxic substances (Tudi et al., 2021). Moreover, spraying pesticides in rice fields presents additional difficulties due to water, low-lying patches, and salinity resulting from monocropping practices.

On the other hand, aerial application systems, such as Unmanned Aerial Vehicles (UAVs), have emerged as a solution to mitigate the risks associated with ground spraying.

UAVs, operated remotely or in autonomous mode, offer enhanced safety for operators by spraying pesticides from above the plants without entering the crop, thereby minimizing the risk of crop damage. Utilizing UAVs provides several advantages, including improved manoeuvrability, light weight, increased efficiency, timely coverage of larger areas, and the ability to spray in complex terrains. As a result, the adoption of UAVs in agriculture is expected to experience significant growth over the next decade. According to global market intelligence and advisory firm BIS research, the global drone market, which is currently dominated by US, China, and Israel, will touch \$28.47 billion [Rs 209,692 crore] this year, out of which India will contribute about 4.25 per cent. The drone market in India is expected to reach \$1.21 billion (Rs 8,911 crore) in CY 2021. It is likely to touch \$1.81 billion (Rs 13,330 crore) by FY 2026 growing at a compound annual growth rate (CAGR) of 14.61 percent. Therefore, Govt. of India is focusing on bringing drone-based technologies in agriculture and implementing pro-drone policies as one of the must have technology.

However, despite the numerous benefits offered by drone spraying, there are compatibility issues that need to be addressed. Farmers often need to manage multiple insect pests and diseases simultaneously, requiring either multiple applications of pesticides or the use of pesticide mixtures. The inadequate knowledge of pesticide compatibility can lead to phytotoxicity or reduced efficacy. Furthermore, information regarding the compatibility of newer combinations of insecticides and fungicides is scarce and insufficient, particularly when applied using drone spraying equipment. Incompatibility between pesticides can result in phytotoxicity, reduced efficacy, or even contribute to pesticide resistance (Peshney, 1990).

To address these concerns, an experiment was conducted to test the physical compatibility of pesticide combinations at drone spraying concentrations in comparison with taiwan sprayer concentrations. This experiment was aimed to provide insights into the compatibility of pesticide mixtures for drone spraying and to ensure their safe and effective use in the field.

Materials and Methods

The experiment was conducted at Institute of Rice Research, ARI, PJTSAU, Rajendranagar, Hyderabad during 2022. The physical compatibility of 10 individual pesticides as represented in table 1 (5 insecticides and 5 fungicides) and their combinations (25) with drone and manual spraying (taiwan sprayer) concentrations were evaluated under laboratory conditions by conducting jar compatibility test as prescribed by Indian Standards Specifications (IS, 1973) and pH of all pesticides individually and in combinations was measured by using pH meter under laboratory conditions. The standard reference temperature used for calibration was 25 °C

(Rajasekar and Mallapur, 2017). For jar compatibility test, the water was taken from the same water source that was used for tank mixes. Measured quantity of water was taken in a one-litre jar to which one insecticide and fungicide were added at recommended doses in the following order as per “WALES” (Suganthi *et al.*, 2010) wettable powder (WP) and water dispersible granules (WDG), liquid flowables and suspensions, emulsifiable concentrates (EC) and soluble concentrates (SC). Then, the volume was made up to one liter with hard water, agitated by shaking the jar and transferred 100 ml of this pesticide solution to 100 ml knobbed and calibrated measuring cylinder and left undisturbed for 60 minutes. Observations were recorded after 30 and 60 minutes with respect to foaming and sedimentation. Also, pH of insecticides and fungicides alone and in combinations both at taiwan and drone spraying dose was recorded. While measuring pH, the samples of pesticide solution were stirred for a few seconds, further allowed the values to stabilize and finally recorded readings.

Results and Discussion:

From the results of jar compatibility test as represented in table 2, out of the 25 combinations tested, foaming and sedimentation was not observed in any of the combinations at taiwan sprayer concentrations. However, at the drone spraying concentrations foaming of 20 ml/l was observed with cartap hydrochloride in combination with picoxystrobin + tricyclazole and cartap hydrochloride in combination with tebuconazole + trifloxystrobin. Similarly, tetraniliprole in combination with prochloraz + tricyclazole, cartap hydrochloride in combination with prochloraz + tricyclazole, flubendiamide in combination with picoxystrobin + propiconazole, flubendiamide in combination with prochloraz + tricyclazole and acephate + imidacloprid in combination with prochloraz + tricyclazole shown foaming of 15ml/l. The rest of the combinations showed no foaming or sedimentation and blended properly. The results of the present study are in line with reports of Visalakshmi *et al.* (2016) conducted lab and field experiments in rice to evaluate the compatibility and efficacy of five insecticides *viz.*, chlorantraniliprole 18.5 % SC, chlorpyrifos 20 % EC, cartap hydrochloride 50 SP, flubendiamide 480 SC, profenofos 50 EC with two fungicides propiconazole and trifloxystrobin 25 % + tebuconazole 50 % and concluded that all the combinations are physically compatible. Sandhya *et al.* (2021) conducted a laboratory experiment to study the physical compatibility of four insecticides lambda cyhalothrin 4.6 % + chlorantraniliprole 9.8 % EC, chlorantraniliprole 18.5 % SC, flubendiamide 39.35 % SC, azadirachtin 1500 ppm and two fungicides azoxystrobin 18.4 % + difenoconazole 11.4 % SC, carbendazim 12 % + mancozeb 63 % WP and the results shown that all the combinations are physically compatible. Prajapati *et al.* (2005) studied the physical compatibility of insecticides *viz.*, cartap hydrochloride 50 WP (0.05 %) and triazophos

20 EC (0.02 %) with fungicides *viz.*, carbendazim 50 WP (0.05 %), tricyclazole 75 WP (0.04 %), propiconazole 25 EC (0.025 %) and hexaconazole 5 EC (0.01 %) in rice and stated that cartap hydrochloride can be mixed with all the fungicides tested but triazophos is compatible with only carbendazim and tricyclazole. Bhatnagar (2004) evaluated the compatibility of pesticides against rice leaf folder and blast. Insecticides *viz.*, triazophos 20 EC, cartap hydrochloride 50 WP and fungicides *viz.*, tricyclazole 75 WP, carbendazim 50 WP were evaluated by jar compatibility test and reported that all the combinations are physically compatible.

The pH of pesticide mixtures will have profound influence on the bio-efficacy of the pesticides and also affect the plants by resulting in phytotoxicity. In this study, the pH of individual pesticides was examined at taiwan sprayer concentrations and drone spraying concentrations, as shown in table 3. Additionally, table 4 presents the pH values of pesticide combinations at both taiwan sprayer concentrations and drone spraying concentrations. Comparing the pH of pesticide combinations at drone spraying concentrations to that of taiwan sprayer concentrations, slight variations were observed. The pH of pesticide combinations at drone spraying concentrations tended to decrease, resulting in more acidic pesticide solutions compared to taiwan sprayer concentrations. Certain combinations involving the pesticide cartap hydrochloride 50% SP, when applied with both sprayer types, resulted in moderately to very strongly acidic conditions. These combinations may require additional pH adjustment measures for effective application. However, none of the pesticide combinations, at either taiwan sprayer concentrations or drone spraying concentrations, exhibited an alkaline pH. This suggests that the pesticide combinations remained resistant to alkaline degradation. Consequently, none of the pesticide combinations exhibited sedimentation in the jar compatibility test, further supporting their stability. The outcome of the present study is in line with the findings of Seaman and Riedl (1976) who revealed that azadiractin (Azatin XL) should be maintained at pH 5-7 and applied soon after mixing which otherwise will rapidly hydrolyzes in more acidic or alkaline conditions.

Table 1 Details of insecticides and fungicides tested for physical compatibility

S.no	Pesticides	Trade name	Recommended dose (g or ml ha ⁻¹)	Taiwan sprayer dose (g or ml lit ⁻¹ of water)	Drone spraying dose (g or ml lit ⁻¹ of water)	Source of supply
1	Chlorantraniliprole 18.5% SC	Coragen	@ 150 ml	0.4 ml	3.75 ml	FMC India Pvt.Ltd., Gujarat.
2	Tetraniliprole 200 SC	Vayego	@ 200 ml	0.6 ml	6.25 ml	Bayer Crop Science Ltd., Mumbai.
3	Cartap hydrochloride 50% SP	Caldan	@ 1000 g	2.66 g	25 g	Dhanuka Agritech Ltd., Ahmadabad
4	Flubendiamide 39.35% SC	Fame	@ 50 ml	0.13 ml	1.25 ml	Bayer Crop Science Ltd., Mumbai.
5	Acephate 50% + Imidacloprid 1.8% SP	Starthene Power	@ 1250 g	3.33 g	18.75 g	SWAL Corporation Ltd. New Delhi.
6	Picoxystrobin 7.5% + Tricyclazole 22.5% SC	Galileo Sensa	@ 1000 ml	2.66 ml	25 ml	Dupont India Pvt.Ltd., Gujarat.
7	Azoxystrobin 18.2% + Difenconazole 11.4% SC	Amistar Top	@ 500 ml	1.33 ml	12.5 ml	Syngenta India Ltd., Mumbai
8	Tebuconazole 50% + Trifloxystrobin 25% WG	Nativo	@ 200 g	0.5 g	4.68 g	Bayer Crop Science Ltd., Mumbai.
9	Picoxystrobin 7% + Propiconazole 12% SC	Galileo Way	@ 1000 ml	2.66 ml	25 ml	Dupont India Pvt.Ltd., Gujarat.
10	Prochloraz 23.5% + Tricyclazole 20% SE	Blacil	@ 1000 ml	2.66 ml	25 ml	Adama India Pvt.Ltd. Gujarat.

Table 2 Physical compatibility of insecticides and fungicides

S. No	Pesticide combinations	Taiwan sprayer concentration			Drone concentration		
		Foaming (ml/l)	Sedimentation (ml/l)	Compatibility Reaction	Foaming (ml/l)	Sedimentation (ml/l)	Compatibility Reaction
1	Chlorantraniliprole 18.5% SC + Picoxystrobin 7.5% + Tricyclazole 22.5% SC	0	0	Compatible	0	0	Compatible
2	Chlorantraniliprole 18.5% SC + Azoxystrobin 18.2% + Difenconazole 11.4% SC	0	0	Compatible	0	0	Compatible
3	Chlorantraniliprole 18.5% SC + Tebuconazole 50% + Trifloxystrobin 25% WG	0	0	Compatible	0	0	Compatible
4	Chlorantraniliprole 18.5% SC + Picoxystrobin 7% + Propiconazole 12% SC	0	0	Compatible	0	0	Compatible
5	Chlorantraniliprole 18.5% + Prochloraz 23.5% + Tricyclazole 20% SE	0	0	Compatible	0	0	Compatible
6	Tetraniliprole 200 SC + Picoxystrobin 7.5% + Tricyclazole 22.5% SC	0	0	Compatible	0	0	Compatible
7	Tetraniliprole 200 SC + Azoxystrobin 18.2% + Difenconazole 11.4% SC	0	0	Compatible	0	0	Compatible
8	Tetraniliprole 200 SC + Tebuconazole 50% + Trifloxystrobin 25% WG	0	0	Compatible	0	0	Compatible
9	Tetraniliprole 200 SC + Picoxystrobin 7% + Propiconazole 12% SC	0	0	Compatible	0	0	Compatible
10	Tetraniliprole 200 SC + Prochloraz 23.5% + Tricyclazole 20% SE	0	0	Compatible	15	0	Incompatible
11	Cartap hydrochloride 50% SP + Picoxystrobin 7.5% + Tricyclazole 22.5% SC	0	0	Compatible	20	0	Incompatible
12	Cartap hydrochloride 50% SP + Azoxystrobin 18.2% + Difenconazole 11.4% SC	0	0	Compatible	0	0	Compatible

13	Cartap hydrochloride 50% SP + Tebuconazole 50% + Trifloxystrobin 25% WG	0	0	Compatible	20	0	Incompatible
14	Cartap hydrochloride 50% SP + Picoxystrobin 7% + Propiconazole 12% SC	0	0	Compatible	0	0	Compatible
15	Cartap hydrochloride 50% SP + Prochloraz 23.5% + Tricyclazole 20% SE	0	0	Compatible	15	0	Incompatible
16	Flubendiamide 39.35% SC + Picoxystrobin 7.5% + Tricyclazole 22.5% SC	0	0	Compatible	0	0	Compatible
17	Flubendiamide 39.35% SC + Azoxystrobin 18.2% + Difenconazole 11.4% SC	0	0	Compatible	0	0	Compatible
18	Flubendiamide 39.35% SC + Tebuconazole 50% + Trifloxystrobin 25% WG	0	0	Compatible	0	0	Compatible
19	Flubendiamide 39.35% SC + Picoxystrobin 7% + Propiconazole 12% SC	0	0	Compatible	15	0	Incompatible
20	Flubendiamide 39.35% SC + Prochloraz 23.5% + Tricyclazole 20% SE	0	0	Compatible	15	0	Incompatible
21	Acephate 50% + Imidacloprid 1.8% SP + Picoxystrobin 7.5% + Tricyclazole 22.5% SC	0	0	Compatible	0	0	Compatible
22	Acephate 50% + Imidacloprid 1.8% SP + Azoxystrobin 18.2% + Difenconazole 11.4% SC	0	0	Compatible	0	0	Compatible
23	Acephate 50% + Imidacloprid 1.8% SP + Tebuconazole 50% + Trifloxystrobin 25% WG	0	0	Compatible	0	0	Compatible
24	Acephate 50% + Imidacloprid 1.8% SP + Picoxystrobin 7% + Propiconazole 12% SC	0	0	Compatible	0	0	Compatible
25	Acephate 50% + Imidacloprid 1.8% SP + Prochloraz 23.5% + Tricyclazole 20% SE	0	0	Compatible	15	0	Incompatible

Table 3 pH of individual pesticides at taiwan and drone sprayer concentrations

S. No	Pesticides	Taiwan sprayer concentration		Drone concentration	
		pH	Nature	pH	Nature
1	Chlorantraniliprole 18.5% SC	6.32	Slightly acidic	6.28	Slightly acidic
2	Tetraniliprole 200 SC	6.50	Slightly acidic	6.32	Slightly acidic
3	Cartap hydrochloride 50% SP	5.68	Moderately acidic	4.97	Very strongly acidic
4	Flubendiamide 39.35% SC	6.27	Slightly acidic	6.24	Slightly acidic
5	Acephate 50% + Imidacloprid 1.8% SP	6.23	Slightly acidic	5.93	Moderately acidic
6	Picoxystrobin 7.5% + Tricyclazole 22.5% SC	6.44	Slightly acidic	6.42	Slightly acidic
7	Azoxystrobin 18.2% + Difenoconazole 11.4% SC	6.40	Slightly acidic	6.38	Slightly acidic
8	Tebuconazole 50% + Trifloxystrobin 25% WG	6.58	Neutral	6.68	Neutral
9	Picoxystrobin 7% + Propiconazole 12% SC	6.32	Slightly acidic	6.28	Slightly acidic
10	Prochloraz 23.5% + Tricyclazole 20% SE	6.60	Neutral	6.38	Slightly acidic

Table 4 pH of insecticide and fungicide combinations at taiwan and drone sprayer concentrations

S. No	Pesticide combinations	Taiwan sprayer concentration		Drone concentration	
		pH	Nature	pH	Nature
1	Chlorantraniliprole 18.5% SC + Picoxystrobin 7.5% + Tricyclazole 22.5% SC	6.59	Neutral	6.42	Slightly acidic
2	Chlorantraniliprole 18.5% SC + Azoxystrobin 18.2% + Difenconazole 11.4% SC	6.71	Neutral	6.32	Slightly acidic
3	Chlorantraniliprole 18.5% SC + Tebuconazole 50% + Trifloxystrobin 25% WG	6.70	Neutral	6.64	Neutral
4	Chlorantraniliprole 18.5% SC + Picoxystrobin 7% + Propiconazole 12% SC	6.59	Neutral	6.40	Slightly acidic
5	Chlorantraniliprole 18.5% + Prochloraz 23.5% + Tricyclazole 20% SE	6.63	Neutral	6.40	Slightly acidic
6	Tetraniliprole 200 SC + Picoxystrobin 7.5% + Tricyclazole 22.5% SC	6.60	Neutral	6.49	Slightly acidic
7	Tetraniliprole 200 SC + Azoxystrobin 18.2%SC + Difenconazole 11.4% SC	6.62	Neutral	6.63	Neutral
8	Tetraniliprole 200 SC + Tebuconazole 50% + Trifloxystrobin 25% WG	6.88	Neutral	6.70	Neutral
9	Tetraniliprole 200 SC + Picoxystrobin 7% + Propiconazole 12% SC	6.66	Neutral	6.50	Slightly acidic
10	Tetraniliprole 200 SC + Prochloraz 23.5% + Tricyclazole 20% SE	6.70	Neutral	6.45	Slightly acidic
11	Cartap hydrochloride 50% SP + Picoxystrobin 7.5% + Tricyclazole 22.5% SC	5.63	Moderately acidic	4.83	Very Strongly acidic
12	Cartap hydrochloride 50% SP + Azoxystrobin 18.2%SC + Difenconazole 11.4% SC	5.62	Moderately acidic	4.87	Very Strongly acidic

13	Cartap hydrochloride 50% SP + Tebuconazole 50% + Trifloxystrobin 25% WG	5.63	Moderately acidic	4.97	Very Strongly acidic
14	Cartap hydrochloride 50% SP + Picoxystrobin 7% + Propiconazole 12% SC	5.63	Moderately acidic	4.90	Very Strongly acidic
15	Cartap hydrochloride 50% SP + Prochloraz 23.5% + Tricyclazole 20% SE	5.61	Moderately acidic	5.00	Very Strongly acidic
16	Flubendiamide 39.35% SC + Picoxystrobin 7.5% + Tricyclazole 22.5% SC	6.62	Neutral	6.56	Neutral
17	Flubendiamide 39.35% SC + Azoxystrobin 18.2%SC + Difenconazole 11.4% SC	6.60	Neutral	6.52	Neutral
18	Flubendiamide 39.35% SC + Tebuconazole 50% + Trifloxystrobin 25% WG	6.77	Neutral	6.64	Neutral
19	Flubendiamide 39.35% SC + Picoxystrobin 7% + Propiconazole 12% SC	6.61	Neutral	6.52	Neutral
20	Flubendiamide 39.35% SC + Prochloraz 23.5% + Tricyclazole 20% SE	6.64	Neutral	6.60	Neutral
21	Acephate 50% + Imidacloprid 1.8% SP + Picoxystrobin 7.5% + Tricyclazole 22.5% SC	6.40	Slightly acidic	5.90	Moderately acidic
22	Acephate 50% + Imidacloprid 1.8% SP + Azoxystrobin 18.2% + Difenconazole 11.4% SC	6.42	Slightly acidic	5.90	Moderately acidic
23	Acephate 50% + Imidacloprid 1.8% SP + Tebuconazole 50% +Trifloxystrobin 25% WG	6.50	Slightly acidic	5.83	Moderately acidic
24	Acephate 50% + Imidacloprid 1.8% SP + Picoxystrobin 7% + Propiconazole 12% SC	6.35	Slightly acidic	5.82	Moderately acidic
25	Acephate 50% + Imidacloprid 1.8% SP + Prochloraz 23.5% + Tricyclazole 20% SE	6.41	Slightly acidic	5.83	Moderately acidic

Conclusion

It is evident from the jar compatibility test results that out of 25 pesticide combinations at taiwan sprayer concentrations and at drone spraying concentration evaluated, 25 combinations of taiwan sprayer concentration and 18 combinations of drone spraying concentration showed neither foaming nor sedimentation, while the remaining seven combinations at drone spraying concentrations showed foaming ranging from 15-20 ml/l. These seven combinations were treated as physically incompatible and rest of the combinations can be takeover to semi-field and field conditions for further tests like bio-efficacy and phytotoxicity studies.

Future Scope

Integrating the compatible pesticide combinations with other pest management approaches, such as biological control, cultural practices, and resistant crop varieties, to develop holistic and sustainable IPM strategies for rice cultivation. Future research avenues would contribute to a deeper understanding of the identified pesticide combinations, their practical applications, and their potential benefits in terms of pest control, crop protection, and environmental sustainability.

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