Compatibility Studies on Selective Insecticides, Fungicides and Water-Soluble Fertilizer Mixtures in Soybean

ABSTRACT

In present context, there is a demand for combination spray of insecticides and fungicides to manage both insect pests and diseases simultaneously in a crop season. However, tank mixing of incompatible combinations can affect the effectiveness of the chemicals, cause phytotoxicity or development of insecticide resistance in pests. Hence, A laboratory experiment were conducted at Agricultural Research Station (UAS, Dharwad), Sankeshwar, Karnataka to study the physical, chemical and phytotoxic compatibility of selective insecticides, fungicides and water-soluble fertilizer mixtures at their recommended dosage in soybean by jar compatibility method. Among eighteen different combinations tested emamectin benzoate 5 SG (0.3 g/l) in combination with propiconazole 25 EC (1 ml/l) and 19:19:19 (N:P:K @ 5 g/l), as well as lambda cyhalothrin 4.6 + chlorantraniliprole 9.3 ZC (0.4 ml/l) in combination with propiconazole 25 EC (1 ml/l) and 19:19:19 (5 g/l) exhibited sedimentation levels of 1 ml l^{-1} which was less than the limits of 2ml/100ml as specified in 1973 by Indian Standard Institute, 1973. The pH of agrochemicals both alone and combinations was evaluated by using a digital pH meter, all the test solutions were in the range of 6.02 to 8.39 and none of the solutions was extremely acidic nor extremely alkaline. No phytotoxic symptoms were observed in combination treatments at 5th and 10th days after spraying. Hence, all the combinations were physically, chemically and biologically compatible.

KEYWORDS: Agrochemicals, Compatibility, Foaming, Phytotoxicity, Sedimentation

1. INTRODUCTION

Soybean, scientifically known as *Glycine max* (L.) Merrill, belongs to the Fabaceae family. It has been recognized as a remarkable crop and has been given various titles such as wonder crop and golden bean in the 20th century(). It is also hailed as the miracle crop of the 21st century. This is because soybean contains an impressive composition of over 40 per cent protein and 20 per cent oil. Due to its nutritional value, soybean is considered as the most important seed legume globally and is primarily grown for its seeds [1].

Soybean is a significant oilseed crop in the rainfed agroecosystems of central and peninsular India. It is cultivated over a vast area of 132.26 million hectares worldwide, producing a substantial output of 385.52 million tonnes with a productivity rate of 2.88 metric tonnes. India is the fifth-largest producer of soybean globally trailing behind China, the United States, Argentina and Brazil. In India, soybean is grown on 11.44 million hectares of land, yielding a total of 12.03 million tonnes with an average of 1051 kilograms per hectare. The prominent states in India for soybean production are Madhya Pradesh, Maharashtra, Rajasthan, Andhra Pradesh, Karnataka and Gujarat. In Karnataka,

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soybean is cultivated on 0.43 million hectares of land, resulting in an output of 0.44 million tonnes and a productivity rate of 1005 kg/ha [2].

The need for combined sprays containing both insecticides and fungicides has risen due to simultaneous occurrence of insect pest and disease during crop seasons. However, blending or tank mixing and applying multiple chemical sprays require careful consideration. Success depends on positive interactions between the components, while mixing antagonistic substances can lead to failures. Challenges may arise from physical incompatibility, reduced effectiveness, potential harm to plants (phytotoxicity) and the risk of insecticide resistance in pest populations [3,4] Balancing these factors is crucial when seeking effective solutions for crop protection.

Misusing of pesticide combinations without proper knowledge can reduce their effectiveness in controlling pests and diseases [5]. Physical compatibility refers to the ability of different pesticide components to be mixed without changing properties like colour, solubility, pH and stability. Phytotoxicity is the harm caused to plants when using certain pesticide in combinations, even if those pesticides are safe individually. Phytotoxic symptoms include leaf damage, chlorotic spots dark pits on fruits, reddish veins, discolored leaf margins, wrinkled leaves, reduced growth, tissue death, scorching, bleaching and wilting [3, 6].

2. MATERIALS AND METHODS

The experiment was conducted at Agricultural Research Station (UAS, Dharwad), Sankeshwar in *Kharif* during 2022-23 in soybean. The compatibility study of twelve agrochemicals which involved nine insecticides, two fungicides and one water soluble fertilizer were tested at recommended dosage, and these agrochemicals formed a total of eighteen combinations and were tested for their physical, chemical and phytotoxic compatibility with jar compatibility test by following standard procedures (References???).

2.1 PHYSICAL AND CHEMICAL COMPATIBILITY

The glassware employed in the experiment underwent a comprehensive cleaning regimen. Initially, the glassware was subjected to a detergent cleansing process, followed by rinsing with tap water. Subsequently, the glassware was immersed in an acid cleaning solution. This solution, created by dissolving 500 grams of potassium dichromate in 5000 ml of distilled water and supplemented with 500 ml of sulphuric acid, was introduced slowly into the container along its walls. The glassware remained within this solution for a duration of approximately four to five hours, after which it was meticulously washed anew using flowing tap water, ensuring the complete removal of any residual traces of the acid solution.

2.2 JAR COMPATIBILITY TEST

To conduct the experiment, one litre capacity beakers was cleaned and filled initially with 500 ml of water. The source of water was from bore well with pH of 7.21. The same source of water was

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used to fill the tank during the pesticide spray. The test insecticides/fungicides (undiluted chemical as per dilution factor) were added in the following order:

1) Wettable Powder (WP)
2) Wettable Granules (WG)
3) Water soluble Granules (SG)
4) Soluble Concentrates (SC)
5) Emulsifiable Concentrate (EC)
6) Zeon Capsule (ZC)

The volume of this insecticide, fungicide and fertilizer mixture was made up to one litre. The mixture was stirred after each addition. The jars were capped tightly with lids and were turned up and down 10 times and later were kept undisturbed for 30 minutes. Observations recorded after 30 and 60 minutes for each treatment and evaluated visually for physical incompatible phenomena like foaming and sedimentation. Limit for sedimentation is 2 ml/100 ml [7]. Height of foaming was rated on 0-3 scale [8].

SCALE	FOAM
0	No foam
1	1 – 10 mm foam
2	11 – 20 mm foam
3	>20 mm foam

Chemical compatibility was tested by conducting pH analysis using digital pH meter, for all the treatments. The solution prepared for jar compatibility test was taken individually in each beaker and the pH electrode was immersed to record the pH values [9] and the test solutions was classified (Table 1)

2.3 PHYTOTOXIC INCOMPATIBILITY DUE TO COMBINATION OF DIFFERENT AGROCHEMICALS

The phytotoxicity of insecticides and fungicides, both individually and in combination, was assessed in the field. The pesticidal solution was sprayed at the recommended dosage, and observations were recorded on five randomly chosen plants in each treatment plot for phytotoxicity symptoms such as leaf damage, chlorotic spots, dark pits on fruits, reddish veins, discolored leaf margins, wrinkled leaves, reduced growth, tissue death, scorching, bleaching and wilting. These observations were recorded one day before spraying and again on the 5th and 10th day after spraying. The extent of phytotoxicity was measured using the scale provided by the Central Insecticide Board and Registration Committee (C.I.B and R.C) [10] (Table 2). The percentage of injury was calculated by using the following formula.

$$\text{Per cent injury} = \frac{\text{Total Grade points}}{\text{Maximum grade} \times \text{No. of leaves observed}} \times 100$$

2.4 DATA ANALYSIS

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3. RESULTS AND DISCUSSION

Eighteen combinations of insecticides, fungicides and water-soluble fertilizer mixtures were examined to assess their potential for foaming and sedimentation. Among the various combinations tested, it was found that emamectin benzoate 5 SG (0.3 g/l) in combination with propiconazole 25 EC (1 ml/l) and 19:19:19 (N:P:K @ 5 g/l), as well as lambda cyhalothrin 4.6 + chlorantraniliprole 9.3 ZC (0.4 ml/l) in combination with propiconazole 25 EC (1 ml/l) and 19:19:19 (5 g/l), exhibited sedimentation levels of 1 ml l^{-1} (Table 3). These levels were found to be below the specified limits of 2 ml/100 ml as set by ISI.

It is worth noting that none of the remaining combination solutions of insecticides, fungicides, and water-soluble fertilizer mixtures displayed any sedimentation or foaming issues. Consequently, it can be concluded that all the tested combinations of insecticides, fungicides and water-soluble fertilizer mixtures were physically compatible at their recommended doses and can be readily utilized for crop spraying purposes. However, altering the dosage of what could lead to changes in the sedimentation tendency and may also notice foaming within these specific agrochemical combinations.

The present findings are in agreement with Visalakshmi *et al*. [11] who reported that five insecticides *viz*., chlorantraniliprole 18.5 SC, chlorpyriphos 20 EC, cartap hydrochloride 50 SP, flubendamide 480 SC and profenophos 50 EC @ 0.3 ml/l, 2.5 ml/l, 2 g/l, 0.25 ml/l, 2 ml/l, respectively and two fungicides *viz*., trifloxystrobin 25 + tebuconazole 50 WG @ 0.4g/l and propiconazole 25 EC at recommended concentrations, all these combinations were physically compatible in paddy. Similar results were recorded by Sandhya *et al*. [12] in maize crop.

The pH of ~~test~~ pesticides test alone and in combinations was tested by using digital pH meter. The pH of all the test solutions was in the range of 6.02 to 8.39 (Table 4). Among the insecticides, fungicides and water soluble fertilizer tested alone all the nine insecticides *viz*., quinalphos 20 EC with pH of 8.24, lambda cyhalothrin 5 EC (pH 8.27), flubendiamide 39.35 SC (pH 8.28), thiamethoxam 25 WG (8.29), chlorantraniliprole 18.5 SC (8.35), spinosad 45 SC (8.33), emamectin benzoate 5 SG (pH 8.39), lambda cyhalothrin 4.6 + chlorantraniliprole 9.3 ZC (pH 8.32) and thiamethoxam 12.6 + lambda cyhalothrin 9.5 ZC (pH 8.34), as well as two fungicides *viz*., propiconazole 25 EC and tebuconazole 50 + trifloxystrobin 25 WG recorded pH of 8.35 and 8.36, respectively were moderately alkaline and one water soluble fertilizer 19:19:19 recorded with neutral pH of 7.03.

Among all the combinations tested, thiamethoxam 12.6 + lambda cyhalothrin 9.5 ZC in conjunction with propiconazole 25 EC and 19:19:19, as well as lambda cyhalothrin 4.6 + chlorantraniliprole 9.3 ZC + propiconazole 25 EC + 19:19:19, exhibited a moderate level of acidity, with pH values of 6.02 and 6.03, respectively.

The combination of quinalphos 20 EC with tebuconazole 50 + trifloxystrobin 25 WG and 19:19:19 resulted in pH of 6.56. Additionally, the mixture of flubendiamide 39.35 SC + tebuconazole 50 + trifloxystrobin 25 WG + 19:19:19 (pH 6.56), thiamethoxam 25 WG + tebuconazole 50 +

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The combination of quinalphos 20 EC and propiconazole 25 EC with 19:19:19 resulted in a pH of 6.90, lambda cyhalothrin 5 EC + propiconazole 25 EC + 19:19:19 (pH 7.08), flubendiamide 39.35 SC + propiconazole 25 EC + 19:19:19 (pH 7.06), thiamethoxam 25 WG + propiconazole 25 EC + 19:19:19 (pH 6.94), chlorantraniliprole 18.5 SC + propiconazole 25 EC + 19:19:19 (pH 6.99), spinosad 45 SC + propiconazole 25EC + 19:19:19 (pH 7.00), emamectin benzoate 5 SG + propiconazole 25 EC + 19:19:19 (pH 6.95) and lambda cyhalothrin 5 EC + tebuconazole 50 + trifloxystrobin 25 WG + 19:19:19 (pH 6.63). All these formulations were found to be neutral in terms of their pH levels.

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The findings demonstrated that when mixing various agrochemical combinations with the spraying water of neutral pH 7.21, all agrochemicals, whether utilized individually or in tandem, maintained pH levels closely aligned with the original water pH. The water employed for agrochemical mixing was sourced from the same origin as the tank mix water. Importantly, none of the solutions displayed excessive acidity or alkalinity. Instead, pH values remained within a chemically compatible range with the close to the nature of the water. This indicates the secure usability of agrochemical combinations for spraying, devoid of any potential for unfavourable chemical reactions or disruptions in pH equilibrium and no phytotoxicity symptoms were observed at 5th and 10th day after spraying (Table 3).

The results of the present investigation are in line with Sabitha [13] reported that eight possible combinations of four insecticides, namely flonicamide 50 WG, pymetrozine 50 WG, chlorantraniliprole 18.5 SC, and acephate 75 SP, along with two fungicides *viz*., azoxystrobin 23 EC and difenoconazole 25 EC. The pH levels of these combinations varied between moderately alkaline to slightly alkaline, while also retaining the pH of the water used for mixing and similar results were presented by Rajasekar B and Mallapur C P [14] in *Bt* cotton.

4. CONCLUSION

Although sedimentation was observed in two treatments among different combinations tested, it was found to be below the specified limit of 2 ml/100 ml set by the ISI in 1973. Therefore, it can be concluded that all of the combinations are physically compatible. However, it is important to note that altering the dosage may result in changes in the sedimentation tendency and could potentially lead to the occurrence of foaming in these specific agrochemical combinations. Furthermore, it should be emphasized that at the prescribed dosage of various agrochemicals and under the current pH of the water, these combinations demonstrated chemical compatibility, effectively avoiding extreme levels of acidity or alkalinity. Nevertheless, it is crucial to acknowledge that variations in dosage and water pH have the potential to cause shifts in the pH of the test solutions, which may ultimately result in chemical incompatibility.

Consent Not applicable

Ethical approval Not applicable

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Table 1. Classification of pH based on nature of reaction

Sl. No.	pH	Nature of pH
1	< 4.5	Extremely acidic
2	4.5 – 5.0	Very strongly acidic
3	5.1 – 5.5	Strongly acidic
4	5.6 – 6.0	Moderately acidic
5	6.1 – 6.5	Slightly acidic
6	6.6 – 7.3	Neutral
7	7.4 – 7.8	Slightly alkaline
8	7.9 – 8.4	Moderately alkaline
9	8.5 – 9.0	Strongly alkaline
10	> 9	Very strongly alkaline

Table 2. Leaf injury assessment by visual ratings in 0 to 10 scale

Scale	Phytotoxicity
0	No phytotoxicity
1	1 to 10 %
2	11 to 20 %
3	21 to 30 %
4	31 to 40 %
5	41 to 50 %
6	51 to 60 %
7	61 to 70 %
8	71 to 80 %
9	81 to 90 %
10	91 to 100 %

Table 3. Physical compatibility of different agrochemicals

Tr. No.	Agrochemical combination	Rec. dosage (g or ml/l)	Sedimentation ml l^{-1}	Foaming ml l^{-1}	Phytotoxicity
1	Quinalphos 20 % EC + Propiconazole 25 % EC + 19:19:19	2 ml + 1 ml + 5 g	0	0	-
2	Lambda cyhalothrin 5 % EC + Propiconazole 25 % EC + 19:19:19	0.5 ml + 1 ml + 5 g	0	0	-
3	Flubendiamide 39.35 % SC + Propiconazole 25 % EC + 19:19:19	0.5 ml + 1 ml + 5 g	0	0	-

4	Thiamethoxam 25 % WG + Propiconazole 25 % EC + 19:19:19	0.3 g + 1 ml + 5 g	0	0	-
5	Chlorantraniliprole 18.5 % SC + Propiconazole 25 % EC + 19:19:19	0.2 ml + 1 ml + 5 g	0	0	-
6	Spinosad 45 % SC + Propiconazole 25 % EC + 19:19:19 +	0.2 ml + 1 ml + 5 g	0	0	-
7	Emamectin benzoate 5 % SG + Propiconazole 25 % EC + 19:19:19	0.3 g + 1 ml + 5 g	1	0	-
8	Lambda cyhalothrin 4.6 % + Chlorantraniliprole 9.3 % ZC + Propiconazole 25% EC + 19:19:19	0.4 ml + 1 ml + 5 g	1	0	-
9	Thiamethoxam 12.6 % + Lambda cyhalothrin 9.5 % ZC+ Propiconazole 25 % EC + 19:19:19	0.25 ml + 1 ml + 5 g	0	0	-
10	Quinalphos 20 % EC + Tebuconazole 50 % + Trifloxystrobin 25 % WG + 19:19:19	2 ml + 0.5 g + 5 g	0	0	-
11	Lambda cyhalothrin 5 EC + Tebuconazole 50 + Trifloxystrobin 25 % WG + 19:19:19	0.5 ml + 0.5 g + 5 g	0	0	-
12	Flubendiamide 39.35 % SC + Tebuconazole 50 % + Trifloxystrobin 25% WG + 19:19:19	0.5 ml + 0.5 g + 5 g	0	0	-
13	Thiamethoxam 25 % WG + Tebuconazole 50 % + Trifloxystrobin 25 % WG + 19:19:19	0.3 g + 0.5 g + 5 g	0	0	-
14	Chlorantraniliprole 18.5 % SC + Tebuconazole 50 % + Trifloxystrobin 25 % WG + 19:19:19	0.2 ml + 0.5 g + 5 g	0	0	-
15	Spinosad 45 % SC + Tebuconazole 50 % + Trifloxystrobin 25% WG + 19:19:19	0.2 ml + 0.5 g + 5 g	0	0	-
16	Emamectin benzoate 5 % SG + Tebuconazole 50 % + Trifloxystrobin 25 %WG + 19:19:19	0.3 g + 0.5 g + 5 g	0	0	-
17	Lambda cyhalothrin 4.6 % + Chlorantraniliprole 9.3 % ZC + Tebuconazole 50 % + Trifloxystrobin 25 % WG + 19:19:19	0.4 ml + 0.5 g + 5 g	0	0	-
18	Thiamethoxam 12.6 % + Lambda cyhalothrin 9.5 % ZC + Tebuconazole 50 % + Trifloxystrobin 25 % WG + 19:19:19	0.25 ml + 0.5 g + 5 g	0	0	-

Table 4. Classification of agrochemicals alone and in combination based on pH range

S. No.	Nature of reaction	pH range	Agrochemical solutions	pH
1	Moderately acidic	5.6-6.0	Thiamethoxam 12.6 + Lambda cyhalothrin 9.5 ZC+ Propiconazole 25 EC + 19:19:19	6.02
			Lambda cyhalothrin 4.6 + Chlorantraniliprole 9.3 ZC + Propiconazole 25 EC + 19:19:19	6.03
2	Slightly acidic	6.1-6.5	Quinalphos 20 EC + Tebuconazole 50 + Trifloxystrobin 25 WG + 19:19:19	6.56
			Flubendiamide 39.35 SC + Tebuconazole 50 + Trifloxystrobin 25 WG + 19:19:19	6.56
			Thiamethoxam 25 WG + Tebuconazole 50 + Trifloxystrobin 25 WG + 19:19:19	6.47
			Chlorantraniliprole 18.5 SC + Tebuconazole 50 + Trifloxystrobin 25 WG + 19:19:19	6.50
			Spinosad 45 SC + Tebuconazole 50 + Trifloxystrobin 25 WG + 19:19:19	6.52
			Emamectin benzoate 5 SG + Tebuconazole 50 + Trifloxystrobin 25 WG + 19:19:19	6.51
			Lambda cyhalothrin 4.6 + Chlorantraniliprole 9.3 ZC + Tebuconazole 50 + Trifloxystrobin 25 WG + 19:19:19	6.56
			Thiamethoxam 12.6 + Lambda cyhalothrin 9.5 ZC + Tebuconazole 50 + Trifloxystrobin 25 WG + 19:19:19	6.57
3	Neutral	6.6-7.3	19:19:19	7.03
			Quinalphos 20 EC + Propiconazole 25 EC + 19:19:19	6.90

S. No.	Nature of reaction	pH range	Agrochemical solutions	pH
			Lambda cyhalothrin 5 EC + Propiconazole 25 EC + 19:19:19	7.08
			Flubendiamide 39.35 SC + Propiconazole 25 EC + 19:19:19	7.06
			Thiamethoxam 25 WG + Propiconazole 25 EC + 19:19:19	6.94
			Chlorantraniliprole 18.5 SC + Propiconazole 25 EC + 19:19:19	6.99
			Spinosad 45% SC + Propiconazole 25EC + 19:19:19	7.00
			Emamectin benzoate 5 SG + Propiconazole 25 EC + 19:19:19	6.95
			Lambda cyhalothrin 5 EC + Tebuconazole 50 + Trifloxystrobin 25 WG + 19:19:19	6.63
4	Moderately alkaline	7.9-8.4	Quinalphos 20 EC	8.24
			Lambda cyhalothrin 5 EC	8.27
			Flubendiamide 39.35 SC	8.28
			Thiamethoxam 25 WG	8.29
			Chlorantraniliprole 18.5 SC	8.35
			Spinosad 45 S	8.33
			Emamectin benzoate 5 SG	8.39
			Lambda cyhalothrin 4.6 + Chlorantraniliprole 9.3 ZC	8.32
			Thiamethoxam 12.6 + Lambda cyhalothrin 9.5 ZC	8.34
			Propiconazole 25 EC	8.35
			Tebuconazole 50 + Trifloxystrobin 25 WG	8.36