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 reduce the effectiveness of the chemicals, cause phytotoxicity or development of insecticide resistance in pests and also induce agrochemical pollution in crop environment. Hence, a laboratory experiment was 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 dose in soybean by jar compatibility method. Out of eighteen different combinations tested emamectin benzoate 5 SG (0.3 g l^{-1}) in combination with propiconazole 25 EC (1 ml l^{-1}) and 19:19:19 (N:P:K @ 5 g l^{-1}), as well as lambda cyhalothrin 4.6 + chlorantraniliprole 9.3 ZC (0.4 ml l^{-1}) in combination with propiconazole 25 EC (1 ml l^{-1}) and 19:19:19 (5 g l^{-1}) exhibited sedimentation levels of 1 ml l^{-1} which was less than the limits of 2 ml 100 ml^{-1} as specified in 1973 by Indian Standard Institute. The pH of agrochemicals both alone and combinations in all solutions test ranged from 6.02 to 8.39 and none of the solutions found extremely acidic nor alkaline. No phytotoxic symptoms were observed in combination treatments at 5th and 10th days after spraying. All test combinations were physically, chemically and biologically compatible hence, tank mixing of these chemicals can be recommended in soybean for managing of insect pest and diseases.

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 [1]. Soybean seeds contain an impressive composition of over 40 % protein and 20 % oil, due to fact that globally it is considered as the most important seed legume [2].

Soybean is a significant oilseed crop in the rainfed agroecosystems of central and peninsular India. In worldwide, it is cultivated over a vast area of 132.26 million hectares. The total production is around 385.52 million tonnes and the average productivity is about 2.88 metric tonnes per hectare. India is the fifth-largest producing country of soybean behind China, 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, soybean is cultivated on 0.43 million hectares of land, resulting in an output of 0.44 million tonne and a productivity rate of 1005 kg/ha [3].

Managing pests in agriculture often requires integrated pest management approaches in which the use of various chemicals and sprays are inevitable. In order to save time, labor and cost of applications farmers go for application of mixture of multiple pesticides and nutrients when dealing with a wide range of pests and diseases. At the same time, these practices can also lead to undesirable problems such as incompatibility in mixing reduces the efficacy of applied chemicals, creates pollution in crop environment and also hazard to people handling the agrochemicals. Specifically, incompatibility among different applied chemicals can result in reduced efficacy, improper application and even damaging the plants [4,5]. The symptoms of phytotoxicity include chlorotic spots (4), foliage injury [6], darkened shallow pits on fruits [7], chlorotic leaf margins and laminas, reddish or purplish veins, wrinkled leaves, death of leaf tissue (necrosis), wilting, whiplashing, scorching and bleaching of foliage and reduced growth [8].

Therefore, before tank mixing it is important to understand the compatibility of different agrochemicals when they are used simultaneously to manage pests and diseases in the field [9]. In this study, experiments were conducted for the first time in India in soybean crop to determine the compatibility of recommended insecticides, fungicides and water-soluble fertilizers. The findings from this research will help farmers and agrochemical applicators to make decisions about the mixing of commonly used chemicals for pest and disease management in soybean crop.

2. MATERIALS AND METHODS

The experiment was conducted at Agricultural Research Station located at Latitude: 16.14N, Longitude: 74.30E and altitude: 698 meters (UAS, Dharwad), Sankeshwar in *Kharif* from June to October (2022) in soybean. The compatibility study of twelve agrochemicals which involved nine insecticides (Quinalphos 20 EC @ 2.0 ml l^{-1}, Lambda cyhalothrin 5 EC @ 0.5 ml l^{-1} , Flubendiamide 39.35 SC @ 0.5 ml l^{-1}, Thiamethoxam 25 WG @ 0.3 g l^{-1}, Chlorantraniliprole 18.5 SC @ 0.2 ml l^{-1} , Spinosad 45 SC @ 0.2 ml l^{-1}, Emamectin benzoate 5 SG @ 0.3 g l^{-1}, Lambda cyhalothrin 4.6 + Chlorantraniliprole 9.3 ZC @ 0.4 ml l^{-1} and Thiamethoxam 12.6 + Lambda cyhalothrin 9.5 ZC @ 0.25 ml l^{-1}), two fungicides (Propiconazole 25 EC @ 1 ml l^{-1} and Tebuconazole 50 + Trifloxystrobin 25 WG @ 0.5 g l^{-1}) and one water soluble fertilizer (19:19:19, N:P:K @ 5 g l^{-1}) were tested at recommended dose. These agrochemicals accounted of eighteen combinations which were tested for their physical, chemical and phytotoxic compatibility with jar compatibility test by following standard procedures [10].

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 [11].

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 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 [12],

1. Wettable Granules (WG): Thiamethoxam 25 WG and Tebuconazole 50 + Trifloxystrobin 25 WG.

2.Water soluble Granules (SG): Emamectin benzoate 5 SG.

3.Soluble Concentrates (SC): Flubendiamide 39.35 SC, Chlorantraniliprole 18.5 SC and Spinosad 45 SC.

4.Emulsifiable Concentrate (EC): Quinalphos 20 EC, Lambda cyhalothrin 5 EC and Propiconazole 25 EC.

5.Zeon Capsule (ZC): Lambda cyhalothrin 4.6 + Chlorantraniliprole 9.3 ZC and Thiamethoxam 12.6 + Lambda cyhalothrin 9.5 ZC.

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 as specified by Indian Standard Institute (ISI) [13].

Height of foaming was rated on 0-3 scale [14].

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

The solution prepared for jar compatibility test was taken individually in each beaker and the pH electrode was immersed to record the pH values [15] and the test solutions was classified based on pH (Table 1).

2.3 PHYTOTOXIC INCOMPATIBILITY OF DIFFERENT AGROCHEMICALS

Observations on phytotoxity were recorded at a day before, 5 and 7 days after spray. Observation for the specific parameters like leaf tip & surface injury, hyponasty, epinasty and scorching were recorded by using scale provided by the Central Insecticide Board and Registration

Committee (C.I.B and R.C) [16] detailed in Table 2.

The per cent injury will be calculated by using the formula [17].

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

3. RESULTS AND DISCUSSION

Among the various combinations tested emamectin benzoate 5 SG (0.3 g l^{-1}) in combination with propiconazole 25 EC (1 ml l^{-1}) and 19:19:19 (N:P:K @ 5 g l^{-1}), as well as lambda cyhalothrin 4.6 + chlorantraniliprole 9.3 ZC (0.4 ml l^{-1}) in combination with propiconazole 25 EC (1 ml l^{-1}) and 19:19:19 (5 g l^{-1}), 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 $^{-1}$ 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 suggested 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 dose of agrochemicals may lead to changes in the sedimentation tendency and also notice foaming within these specific combinations.

The present findings are in agreement with Visalakshmi *et al*. [18] 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^{-1}, 2.5 ml l^{-1}, 2 g l^{-1}, 0.25 ml l^{-1}, 2 ml l^{-1}, respectively and two fungicides *viz*., trifloxystrobin 25 + tebuconazole 50 WG @ 0.4 g l^{-1} and propiconazole 25 EC @ 1 ml l^{-1} all these combinations were physically compatible in paddy. Similar results were recorded by Sandhya *et al*. [19] in maize crop.

The pH of all the test solutions test was ranged from 6.02 to 8.39 (Table 4). 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.

Thiamethoxam 12.6 + lambda cyhalothrin 9.5 ZC + propiconazole 25 EC + 19:19:19 and 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.

Quinalphos 20 EC + tebuconazole 50 + trifloxystrobin 25 WG + 19:19:19 recorded 6.56.of pH. Additionally, the mixture of flubendiamide 39.35 SC + tebuconazole 50 + trifloxystrobin 25 WG + 19:19:19 (pH 6.56), thiamethoxam 25 WG + tebuconazole 50 + trifloxystrobin 25 WG + 19:19:19 (pH 6.47), chlorantraniliprole 18.5 SC + tebuconazole 50 + trifloxystrobin 25 WG + 19:19:19 (pH 6.50), spinosad 45 SC + tebuconazole 50 + trifloxystrobin 25 WG + 19:19:19 (pH 6.52), emamectin benzoate 5 SG + tebuconazole 50 + trifloxystrobin 25 WG + 19:19:19 (pH 6.51), lambda cyhalothrin 4.6 + Chlorantraniliprole 9.3 ZC + tebuconazole 50 + trifloxystrobin 25 WG + 19:19:19 (pH 6.56), and thiamethoxam 12.6 + lambda cyhalothrin 9.5 ZC + tebuconazole 50 + trifloxystrobin 25 WG + 19:19:19 (pH 6.57) were found to be slightly acidic.

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.

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 [20] 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 [21] 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. 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 dose and pH of water have the potential to cause shifts in pH of test solutions, which may ultimately result in chemical incompatibility.

Author contribution

Methuku Anil Kumar: methodology, conducted experiments, recorded observations, analyzed data, writing – original draft. Shiddalingappa V Hugar: Conceptualization, methodology, supervision of experiments, data curation, writing – review and editing. R. Channakeshava: Conceptualization, supervision of experiments, data curation, writing – review and editing. Shalini N Huilgol: Conceptualization, supervision of experiments, data curation, writing – review and editing.

Competing interests

The authors declare no competing interests.

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^{-1})	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
			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

S. No.	Nature of reaction	pH range	Agrochemical solutions	pH
			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