International Journal of Advanced Biochemistry Research

ISSN Print: 2617-4693
ISSN Online: 2617-4707
IJABR 2024; 8(7): 477-480
www.biochemjournal.com
Received: 25-04-2024
Accepted: 28-05-2024

Abhishek Kumar Tamta
Department of Entomology, College of Agriculture, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Udham Singh Nagar, Uttarakhand, India

RP Srivastava
Department of Entomology, College of Agriculture, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Udham Singh Nagar, Uttarakhand, India

Corresponding Author:
Abhishek Kumar Tamta
Department of Entomology, College of Agriculture, Govind Ballabh Pant University of Agriculture and Technology, Pantnagar, Udham Singh Nagar, Uttarakhand, India

Compatibility of herbicide-insecticide-fungicide combinations and their phytotoxicity on soybean

Abhishek Kumar Tamta and RP Srivastava

DOI: https://doi.org/10.33545/26174693.2024.v8.i7f.1508

Abstract
This study evaluated the physical and chemical compatibility of two insecticides (emamectin benzoate and flubendiamide), two herbicides (quizalofop-ethyl and imazamox + imazethapyr), and one fungicide (fluxapyroxad + pyraclostrobin), as well as their combinations, at 25 °C using tap water. Solutions were observed for pH, TDS, EC, solubility, colour, cream volume, and sediment volume over 24 hours. Results showed all individual formulations, except imazamox + imazethapyr, were cloudy but soluble without precipitation. Combination solutions exhibited turbidity but remained soluble. The pH of combinations of emamectin benzoate and flubendiamide with quizalofop-ethyl + fluxapyroxad + pyraclostrobin or imazamox + imazethapyr + fluxapyroxad + pyraclostrobin exhibited pH decreases by 8.0-7.58, 7.87-7.37, 7.73-7.17, and 7.41-7.37, respectively, over 24 h. The tap water pH ranged between 6.90-6.54. The total dissolved solids remained below 500 mg/L. Phytotoxicity tests on soybean PS-1347 revealed no adverse effects at recommended and double doses. The study concluded that the tested pesticide combinations are stable and non-phytotoxic, making them suitable for field application within 24 hours of preparation.

Keywords: Soybean, physical compatibility, chemical compatibility, phytotoxicity, polyhouse

Introduction
In contemporary agriculture, effective pest, weed, and disease management is crucial for achieving optimal crop yields and ensuring food security. This involves the strategic use of insecticides, fungicides, and herbicides, each tailored to combat specific threats to crop health. However, when these agents are combined, interactions may arise that affect their efficacy and safety on crops. CIBRC (2024) [2] has registered combinations of insecticide + insecticide (92), fungicide + fungicide (82), herbicide + herbicide (48), and insecticide + fungicide (6). Notably, combinations involving all three—herbicide, insecticide, and fungicide—have not been extensively studied. Hence, this study aims to explore the physical and chemical compatibility of such combinations, crucial for understanding their stability and effectiveness under varying environmental conditions.

The preparation of pesticide spray solutions in water involves complex chemical processes that can alter pH and other key parameters. This becomes particularly significant when mixing active ingredients with diverse properties in compatibility experiments. Changes in pH can potentially trigger pesticide hydrolysis, compromising their absorption by pests and thereby impacting pest control effectiveness. Achieving compatibility between herbicides and insecticides requires maintaining stable pH conditions to avoid incompatibilities and ensure optimal performance. Factors influencing alkaline hydrolysis include pH levels, temperature, solubility, concentration, humidity, application timing, and the presence of adjuvants, all of which influence the chemical and physical properties of pesticide combinations. Therefore, assessing physical and chemical compatibility is essential for evaluating the hydrolytic stability at room temperature (25 °C) building upon previous research by Stanley *et al.* (2010) [13], Jayasekharan *et al.* (2018 a and b) [6-7], and Madhuri *et al.* (2021) [9].

Materials and Methods
The physical and chemical compatibility of two insecticides *viz.* emamectin benzoate (Super Yodha 1.9 EC) and flubendiamide (Flue 39.35 SC); two herbicides *viz*. quizalofop ethyl

(Targa Super 5% EC) and imazamox + imazethpyr (Odyssey 70% WG); and one fungicide *i.e.*, fluxapyroxad + pyraclostrobin (Prioxar 167 + 333 g/L) at recommended concentrations (CIBRC, 2021) [2], along with their four combinations, were evaluated in laboratory conditions at 25 °C using tap water. Individual solutions (60 ml) and combined solutions (20 ml each in a 1:1:1 ratio) were prepared in stoppered measuring cylinders and shaken vigorously. Observations for pH, total dissolved solids (TDS), electrical conductivity (EC), solubility, colour, cream volume, and sediment volume were recorded at 0.5, 2, 8, and 24 h. (Stanley *et al.*, 2010; Jayashekharan *et al.*, 2018b, Raju *et al.*, 2018, Madhuri *et al*., 2021) [13, 7, 11, 9]. The pH and TDS were measured with a Hach HQ40D portable multi-meter, and EC was calculated using following formula:

$$\text{EC}\ (\mu\frac{\text{S}}{\text{cm}}) = \frac{TDS\ (\frac{mg}{L})}{0.67}$$

Phytotoxicity was tested on soybean PS-1347, seed were procured from the University's Department of Genetics and Plant Breeding. Seeds were sown in 5 L pots with garden soil and farmyard manure at the University's Modern Floriculture Centre. The experiment, replicated thrice, evaluated the effects of recommended (x) and double (2x) doses at 15-day intervals (30, 45, 60 DAS) (Kubendran *et al.*, 2009; Govindan *et al*., 2013; CIBRC, 2014; EPPO, 2014; Vidhyadhari *et al*., 2014; Madhuri *et al*., 2021) [8, 5, 1, 4, 16, 9]. Observations on yellowing, stunting, necrosis, and epinasty/hyponasty were recorded at 1, 3, 7, 9, 11, and 14 days after each spray. Leaf injury and phytotoxicity were rated as per Suneel Kumar *et al.* (2016) [14].

Results and Discussion

Physical compatibility

From the experiment of physical compatibility, it was found that when two insecticides *viz.* emamectin benzoate and flubendiamide; two herbicides *viz.* quizalofop ethyl and imazamox + imazethpyr; and one fungicide *i.e.*, fluxapyroxad + pyraclostrobin; were serially diluted in tap at the room temperature (25 °C), individual market formulations were cloudy in colour, except imazamox + imazethapyr which was clear, over a period of 24 h. and were readily soluble without any precipitation or sediment formation. When insecticide + herbicide + fungicide combinations were prepared in tap water at 25 °C, they exhibited turbidity due to interactions with their respective market formulations of insecticides, herbicides, and the fungicide. Importantly, despite this turbidity, they remained readily soluble without any precipitation or sediment formation.

Chemical compatibility

The chemical parameter, TDS, of insecticides, herbicides, and the fungicide remained below 500 mg/L over 24 hours. The pH of insecticides (emamectin benzoate and flubendiamide) decreased by 0.17 and 0.16 units, respectively. Quizalofop-ethyl (herbicide) remained stable at pH 7.61, while imazamox + imazethapyr increased by 0.06 units. The fungicide (fluxapyroxad + pyraclostrobin) also showed a pH increase by 0.7 units.

Combinations of emamectin benzoate and flubendiamide with quizalofop-ethyl + fluxapyroxad + pyraclostrobin or imazamox + imazethapyr + fluxapyroxad + pyraclostrobin exhibited pH decreases by 0.42, 0.50, 0.56, and 0.37 units, respectively, over 24 hours. The control (tap water) showed a pH decrease of 0.36 units over 24 hours.

The spray solutions of individual market formulations and their combinations maintained near-neutral pH (7-7.9) and TDS below 500 mg/L over 24 hours. Physically, all combinations were cloudy but readily soluble without precipitation or sediment formation. This indicates that the combinations did not undergo alkaline hydrolysis and remained stable, making them suitable for field spraying within 24 hours of preparation.

Phytotoxicity

These combinations were sprayed on soybean plants in polyhouse conditions and none of the combinations at the recommended (x) as well as at the double dose (2x) could cause any phytotoxic symptoms such as injury to the leaf tip and leaf surface, vein clearing, wilting, hyponasty, epinasty, and necrosis. The results proved that all the treatments tested were compatible and did not cause any phytotoxicity to soybean plants. Furthermore, none of the treatments including the control displayed any sign of disease on soybean plants.

Therefore, it could be concluded that the herbicides, insecticides, and the fungicide caused a slight change in the pH of spray fluid when added to water. There was no sedimentation or precipitation, and turbidity remained consistent across combinations. However, market formulation like imazamox + imazethapyr was clear but turned cloudy when mixed with insecticides and the fungicide. Tharp and Sigler (2013) [15] noted that most pesticides are weakly acidic or neutral, suitable for pH ranges of 4 to 7. If water pH exceeds 7, pesticides may undergo hydrolysis, particularly alkaline hydrolysis, which accelerates in pH ranges of 8 to 9. Alkaline or acidic water has higher concentrations of OH^- or H^+ ions compared to neutral water. The rate of hydrolysis depends on the water's buffering capacity (Seaman and Riedl, 1986) [12]. Weak acid pesticides, like ammonium salt of imazethapyr, break down in alkaline solutions, reducing pest absorption and effectiveness (Whiteford *et al*., 1986) [17]. Conversely, weak alkaline pesticides, such as sulfonyl urea, degrade in acidic solutions (Mckie and Johnson, 2002) [10]. Our observations also indicated a slight shift towards acidity in the tap water pH over 24 hours.

Table 1: Physical compatibility of market formulations of certain insecticides, herbicides, a fungicide and their combinations in Tap water at room temperature (25 °C)

S. No.	Treatments* [Herbicide (Trade name) + Insecticide (Trade name)]	Class	Concentration** (%)	Colour 0.5 h.	1 h.	2 h.	8 h.	24 h.
1	Emamectin Benzoate (Super yodha 1.9 EC)[1]	Avermectin	0.002	Cloudy	Cloudy	Cloudy	Cloudy	Cloudy
2	Flubendiamide (Flue 39.35 SC)[1]	Diamide	0.01	Cloudy	Cloudy	Cloudy	Cloudy	Cloudy
3	Quizalofop ethyl (Targa Super 5% EC)[2]	Aryloxyphenoxypropionate	0.02	Cloudy	Cloudy	Cloudy	Cloudy	Cloudy
4	Imazamox + Imazethpyr (Odyssey 70% WG)[2]	Imidazolinone	0.01	Clear	Clear	Clear	Clear	Clear
5	Fluxapyroxad + Pyraclostrobin (Prioxar 167 + 333 g/L)[3]	Carboxamide + Strobilurins	0.03	Cloudy	Cloudy	Cloudy	Cloudy	Cloudy
6	[Quizalofop ethyl (Targa Super 5% EC)] + [Emamectin Benzoate (Super yodha 1.9 EC)] + [Fluxapyroxad + Pyraclostrobin (Prioxar 167 + 333 g/L)]	Aryloxyphenoxy propionate + Avermectin + Carboxamide + Strobilurins	0.02+ 0.002 + 0.03	Cloudy	Cloudy	Cloudy	Cloudy	Cloudy
7	[Quizalofop ethyl (Targa Super 5% EC)] + [Flubendiamide (Flue 39.35 SC)] + [Fluxapyroxad + Pyraclostrobin (Prioxar 167 + 333 g/L)]	Aryloxyphenoxy propionate + Diamide + Carboxamide + Strobilurins	0.02+ 0.01 + 0.03	Cloudy	Cloudy	Cloudy	Cloudy	Cloudy
8	[Imazamox + Imazethpyr (Odyssey 70% WG)] + [Emamectin Benzoate (Super yodha 1.9 EC)] + [Fluxapyroxad + Pyraclostrobin (Prioxar 167 + 333 g/L)]	Imidazolinone + Avermectin + Carboxamide + Strobilurins	0.01+ 0.002 + 0.03	Cloudy	Cloudy	Cloudy	Cloudy	Cloudy
9	[Imazamox + Imazethpyr (Odyssey 70% WG)] + [Flubendiamide (Flue 39.35 SC)] + [Fluxapyroxad + Pyraclostrobin (Prioxar 167 + 333 g/L)]	Imidazolinone + Diamide + Carboxamide + Strobilurins	0.01+ 0.01 + 0.03	Cloudy	Cloudy	Cloudy	Cloudy	Cloudy
10	Control (Tap water)			Clear	Clear	Clear	Clear	Clear

*All the treatments were readily soluble in Tap water. There was no volume of cream (ml) and sediment at bottom (ml)
**All the concentrations taken were based on the dose recommended by CIB&RC, 2021, on soybean; 1: Insecticide; 2: Herbicide; 3: Fungicide; 6 to 9: Herbicide + Insecticide + Fungicide combinations, the combinations were prepared by combining the recommended concentration of herbicide, insecticide, and fungicide in 1:1:1 ratio, respectively.

Table 2: Chemical compatibility of market formulations of certain insecticides, herbicides, a fungicide and their combinations in tap water at room temperature (25 °C)

S. No.	Treatments* [Herbicide (Trade name) + Insecticide (Trade name)]	Class	pH 0.5 h.	2 h.	8 h.	24 h.	Total Dissolved Solids (T.D.S.) mg/l 0.5 h.	2 h.	8 h.	24 h.	Electrical Conductivity (E.C.) µS/cm 0.5 h.	2 h.	8 h.	24 h.
1	Emamectin Benzoate (Super yodha 1.9 EC)[1]	Avermectin	7.67	7.92	7.74	7.50	281	357	325	337	419.40	532.84	485.07	502.99
2	Flubendiamide (Flue 39.35 SC)[1]	Diamide	7.53	7.85	7.56	7.37	327	360	343	330	488.06	537.31	511.94	492.54
3	Quizalofop ethyl (Targa Super 5% EC)[2]	Aryloxyphenoxypropionate	7.61	7.70	7.65	7.61	356	367	354	336	531.34	547.76	528.36	501.49
4	Imazamox + Imazethpyr (Odyssey 70% WG)[2]	Imidazolinone	7.63	7.74	7.66	7.69	354	357	346	349	528.36	532.84	516.42	520.90
5	Fluxapyroxad + Pyraclostrobin (Prioxar 167 + 333 g/L)[3]	Carboxamide + Strobilurins	7.27	7.41	7.68	7.97	260	261	283	261	388.06	389.55	422.39	389.55
6	[Quizalofop ethyl (Targa Super 5% EC)] + [Emamectin Benzoate (Super yodha 1.9 EC)] + [Fluxapyroxad + Pyraclostrobin (Prioxar 167 + 333 g/L)]	Aryloxyphenoxy propionate + Avermectin + Carboxamide + Strobilurins	8.00	8.05	7.14	7.58	249	260	268	263	371.64	388.06	400.00	392.54
7	[Quizalofop ethyl (Targa Super 5% EC)] + [Flubendiamide (Flue 39.35 SC)] + [Fluxapyroxad + Pyraclostrobin (Prioxar 167 + 333 g/L)]	Aryloxyphenoxy propionate + Diamide + Carboxamide + Strobilurins	7.87	7.75	7.12	7.37	256	259	265	260	382.09	386.57	395.52	388.06
8	[Imazamox + Imazethpyr (Odyssey 70% WG)] + [Emamectin Benzoate (Super yodha 1.9 EC)] + [Fluxapyroxad + Pyraclostrobin (Prioxar 167 + 333 g/L)]	Imidazolinone + Avermectin + Carboxamide + Strobilurins	7.73	7.60	7.16	7.17	260	262	265	258	388.06	391.04	395.52	385.07
9	[Imazamox + Imazethpyr (Odyssey 70% WG)] + [Flubendiamide (Flue 39.35 SC)] + [Fluxapyroxad + Pyraclostrobin (Prioxar 167 + 333 g/L)]	Imidazolinone + Diamide + Carboxamide + Strobilurins	7.41	7.37	7.27	7.04	259	259	266	249	386.57	386.57	397.01	371.64
10	Control (tap water)		6.90	7.12	6.80	6.54	6.2	611	607	625	925.37	911.94	905.97	932.84

*All the treatments taken were based on the dose recommended by CIB&RC (2021) on soybean; EC = TDS/0.67; µS/cm = micro siemens per centimetre; 1: Insecticide; 2: Herbicide; 3: Fungicide; 6 to 9: Herbicide + Insecticide + Fungicide combinations, the combinations were prepared by combining the recommended concentration of herbicide, insecticide, fungicide in 1:1:1 ratio.

Conclusion

The present study brings out a concrete understanding for combining the insecticides, herbicides, and fungicides by assessing the physical and chemical properties. The combinations of emamectin benzoate and flubendiamide with quizalofop-ethyl + fluxapyroxad + pyraclostrobin or imazamox + imazethapyr + fluxapyroxad + pyraclostrobin exhibited pH in neutral range (7-7.9) over 24 h. and were found readily soluble without any sedimentation or cream formation. Therefore, the test combinations were found

physically and chemically stable. The phytotoxicity experiments also commemorate the stability of the combinations. Due to the limited research on insecticide-herbicide-fungicide combinations limits our ability of compare the results of pH and TDS or EC. The tested combinations can be further studied for toxicity against various insect pest, diseases, and weeds of soybean crop and other pulse crops.

Acknowledgements
The authors are thankful to Dr. R.M. Srivastava (Professor Entomology) for providing facilities to conduct experiments on physical and chemical compatibility in the Molecular Entomology Laboratory, and Dr. Ranjan Srivasatava (Professor Horticulture) for providing the polyhouse facility in the Model Floriculture Centre of the University to conduct experiments on phytotoxicity.

Competing Interest
Authors have declared that no competing interest exist.

References
1. Central Insecticide Board and Registration Committee, Directorate of Plant Protection quarantine and storage. Test protocol for efficacy evaluation of insecticides; c2014. Available from: http://ppqs.gov.in. Accessed 2024 Jul 5.
2. Central Insecticides Board and Registration Committee, Directorate of Plant Protection quarantine and storage. Insecticide/Pesticides Registered under section 9(3) of the Insecticides Act, 1968 for use in the Country as on 31.11.2021; c2021. Available from: https://ppqs.gov.in/divisions/cib-rc/major-uses-of-pesticides. Accessed 2021 Aug 21.
3. Central Insecticides Board and Registration Committee, Directorate of Plant Protection quarantine and storage. Insecticide/Pesticides Registered under section 9(3) of the Insecticides Act, 1968 for use in the Country as on 31.03.2024; c2024. Available from: https://ppqs.gov.in/divisions/cib-rc/major-uses-of-pesticides. Accessed 2024 Jul 5.
4. European and Mediterranean Plant Protection Organization. PP 1/135 (4) Phytotoxicity assessment. Bulletin OEPP/EPPO. 2014;44(3):265-73. https://doi.org/10.1111/epp.12134.
5. Govindan K, Gunasekaran K, Veeramani K, Kuttalam S. Field and laboratory evaluation of biological compatibility of Emamectin benzoate 5 SG with agrochemicals against okra fruit borer (*Helicoverpa armigera* Hubner). International Journal of Plant and Animal Sciences. 2013;1(8):77-87.
6. Jayasekharan BS, Sreedhar U, Rao GR. Studies on compatibility of biorational insecticides with fungicides against tobacco caterpillar, *Spodoptera litura* Fabricius on tobacco. Indian Journal of Plant Protection. 2018a;46:107-112.
7. Jayasekharan BS, Sreedhar U, Rao GR. Compatibility of insecticide and fungicide mixtures against *Spodoptera litura* (F.) on Virginia tobacco. Indian Journal of Entomology. 2018b;80(4):1574-1579.
8. Kubendran D, Kannan GS, Ganesh S. Assessment of phytotoxicity and compatibility of Flubendamide + Thiacloprid 480 SC (RM) with other agrochemicals. Pestology. 2009;33(5):9-12.
9. Madhuri G, Duraimurugan P, Rani V, Divya S, Sadaiah K, Neelima G, Rajashekar M, Anuradha G, Ramana V. Physical compatibility of insecticides and fungicides and their phytotoxicity on castor. Journal of Oilseeds Research. 2021;37:1-12. https://doi.org/10.56739/jor.v37iSpecialissue.141262.
10. Mckie P, Johnson WS. Water pH and its effect on pesticide stability. University of Nevada, Cooperative Extension Fact Sheet. FD-02-36; c2002.
11. Raju KP. 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. https://doi.org/10.18782/2320-7051.4020.
12. Seaman A, Riedl H. Preventing decomposition of agricultural chemicals by alkaline hydrolysis in the spray tank. New York Food and Life Sciences. 1986;118:7.
13. Stanley J, Chandrasekaran S, Preetha G, Kuttalam S. Physical and biological compatibility of diafenthiuron with micro/macro nutrients fungicides and biocontrol agents used in cardamom. Archives of Phytopathology and Plant Protection. 2010;43(14):1396-406. https://doi.org/10.1080/03235400802476617.
14. Suneel Kumar GV, Satish Y, Sarada O. Evaluation of new insecticides and fungicides for compatibility and management of defoliators and late leaf spot in groundnut. International Journal of Plant and Animal Environmental Sciences. 2016;6(1):58-65.
15. Tharp C, Sigler A. Pesticide performance and water quality. Montana State University Extension. 2013. Available from: https://lewisclark.msuextension.org/documents/MSU_Pesticide_Performance_and_Water_Qual.pdf. Accessed 2024 Jul 5.
16. Vidhyadhari V, Sridevi D, Pushpavathi B, Babu RT. Physical and phytotoxic compatibility of insecticides and fungicides/bactericide on cabbage. Progressive Research. 2014;9:1155-1158.
17. Whiteford F, Penner D, Johson B, Bledsoe L, Wagoner N, Garr J, Wise K, Oberneyer J, Blessing A. The impact of water quality on pesticide performance. Purdue University Extension; c1986.