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Physical and phytotoxic compatibility of new generation insecticides and fungicides on Maize

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Abstract
A lab experiment was carried out at Entomology laboratory, College of Agriculture and field experiment was carried out at College farm, College of Agriculture, Rajendranagar, PJTSAU, Hyderabad to study the physical and phytotoxic compatibility of new generation insecticides and fungicides on maize. Physical compatibility of four insecticides *viz.*, lambda cyhalothrin 4.6% + chlorantraniliprole 9.3% ZC, chlorantraniliprole 18.5% SC, flubendiamide 39.35% SC, azadirachtin 1500 ppm and two fungicides azoxystrobin 18.2% + difenoconazole 11.4% SC, carbendazim 12% + mancozeb 63% WP was evaluated by using jar compatibility test in laboratory and found that all the eight combinations were physically compatible. The pH of insecticides and fungicides was evaluated by using digital pH meter, none of the solution was extremely acidic nor extremely alkaline. The phytotoxic incompatibility due to combination of insecticides and fungicides on maize crop was observed by spraying combination solution on ten selected plants and found that the combinations did not produced any phytotoxic symptoms like chlorotic leaf margins, reddish or purplish veins, wrinkled leaves, necrosis, stunted growth, wilting, whiplashing at 3, 7, 14 days after spraying on maize crop.

Keywords: Physical compatibility, phytotoxic compatibility, jar compatibility test

1. Introduction
Maize (*Zea mays* L.) is one of the most important crops in tropical countries. Maize is cultivated throughout the world and the area is increasing every year than any other grain. It will form the major constituent with wheat and rice, the main proportion of daily food intake of majority people.

Globally maize is called as queen of cereals because it has the highest genetic yield potential among the cereals. United States stands first in maize production with on an average production of 366.6 metric tonnes of maize per year. India produces 28 metric tonnes of maize per year and stands seventh in position in maize production and maize is the second major cultivated crop in the state of Telangana in 14 lakh acres producing annually 16 lakh tonnes.

Maize crop is usually infested with many pests and diseases. The major insect pests of maize in India are pink stem borer [*Sesamia inferens* (Walker)], stem borer [*Chilo partellus* (Swinhoe)], fall armyworm [*Spodoptera frugiperda* (J.E. Smith)]. Major diseases occurring in maize during *rabi* are turcicum leaf blight **[***Exserohilum turcicum***]**, charcoal-rot **[***Macrophamina phaseolina***]**, common rust **[***Puccinia sorghi***]**.

As insect pests and diseases occur simultaneously in a crop season demanding combination spray of insecticides and fungicides. The problem of mixing and spraying more than a single spray chemical is having greater importance in these days. The combinations may be physically incompatible, effect the bioefficacy, result in phytotoxic effects or aid in insecticide resistance development in pests (Peshney, 1990 and Miller *et al.*, 2010) [7, 6]. Injudicious use of pesticides in combinations without proper knowledge may reduce the efficacy of the combinations in managing the pests and diseases (Kubendran *et al.*, 2009) [5].

Physical compatibility is defined as the ability of two or more components of a pesticide mixture to be used in combination without the change in the physical properties like colour, solubility, pH, wettability, emulsion stability. Phytotoxicity is defined as the injury to host plants when two or more pesticides used in combination. Some pesticides are perfectly safe when used alone, but injurious in combination. The symptoms of phytotoxicity include chlorotic spots (Peshney, 1990) [7] and foliage injury (Arthur, 1960), darkened shallow pits on fruits (Poe and Jones, 1972) [8], 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.

2. Materials and Methods

Laboratory experiment (Physical, Chemical compatibility) was conducted at Department of Entomology, field experiment (Phytotoxicity, Efficacy of pesticide combinations) was conducted at College Farm, College of Agriculture, PJTSAU, Rajendranagar during *rabi* 2020-2021.

2.1 Physical compatibility

The physical compatibility of insecticides *viz*., lambda cyhalothrin 4.6% + chlorantraniliprole 9.3% ZC, chlorantraniliprole 18.5% SC, flubendiamide 39.35% SC, azadirachtin 1500 ppm and fungicides azoxystrobin 18.2% + difenoconazole 11.4% SC, carbendazim 12% + mancozeb 63% WP was evaluated by using jar compatibility test. Glassware used in the experiment were firstly cleaned with detergent followed by cleaning in tap water and then placed in the acid cleaning solution prepared by dissolving 500 g of potassium dichromate in 5000 ml of distilled water along with 500 ml of sulphuric acid for about four to five hours and again washed thoroughly with running tap water to remove the traces of acid.

In jar compatibility test standard hard water is used which is prepared by dissolving 0.304 g of calcium chloride and 0.139 g of magnesium chloride hexahydrate in 1 litre of double distilled water. Initially 500 ml of standard hard water is taken in 1 litre glass jar and one insecticide and one fungicide is added to the glass jar at recommended dose in the following order as per "WALES" sequence:

- Wettable powders or water dispersible granules, Agitate then add adjuvants such as anti-foaming compounds, buffers, Liquids (flowable liquids), Emulsifiable concentrates, Surfactants

The volume of insecticide and fungicide mixture was made up to 1 litre with standard hard water, agitated by shaking the jar and left undisturbed for 30 minutes. Observations were recorded after 30 and 60 minutes for foaming and sedimentation.

The pH of insecticides and fungicides alone and in combination was determined by using digital pH meter and the pH readings were recorded the according to Bickelhaupt, Donald (2012) [2] as follows.

Extremely acidic	: < 4.5
Very strongly acidic	: 4.5 – 5.0
Strongly acidic	: 5.1 – 5.5
Moderately acidic	: 5.6 – 6.0
Slightly acidic	: 6.1 – 6.5
Neutral	: 6.6 – 7.3
Slightly alkaline	: 7.4 – 7.8
Moderately alkaline	: 7.9 – 8.4
Strongly alkaline	: 8.5 – 9.0
Very strongly alkaline	: > 9.1

2.2 Phytotoxic incompatibility due to combination of insecticides and fungicides

Phytotoxicity of insecticides and fungicides alone and in combination was evaluated in field by spraying the pesticidal solution on ten selected plants in each treatment plot. Observations of phytotoxicity symptoms like chlorotic leaf margins and laminas, reddish or purplish veins, wrinkled leaves, stunted growth, death of leaf tissue(necrosis), wilting, whiplashing were recorded 1 day before spraying and also on 3rd, 7th, 14th day after spraying. The extent of phytotoxicity was recorded based on the scale described by Central Insecticide Board and Registration Committee (C.I.B and R.C). The per cent injury will be calculated by using the formula (Pullam Raju, 2018) [10].

$$Per\ cent\ injury = \frac{Total\ grade\ points}{\text{Max grade x no.of leaves observed}} \text{ x } 100$$

Table 1: Leaf injury assessment by visual ratings in a 0-10 scale.

Rating	Per cent injury
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 o 100% phytotoxicity

3. Results and Discussion

A total of eight combinations of insecticides and fungicides were examined for foaming, sedimentation. Out of different combinations tested lambda cyhalothrin 4.6%+ chlorantraniliprole 9.3% ZC in combination with carbendazim 12% + mancozeb 63% WP and flubendiamide 39.35% SC in combination with carbendazim 12% + mancozeb 63% WP has recorded 15 ml $l^{-1}$and 5ml l^{-1} of sedimentation, respectively which was less than the limits of 2ml/ 100 ml as specified by ISI.

Neither sedimentation nor foaming was observed in all the remaining combination solutions of insecticides, fungicides and were mixed well without any creamy layer formation. Therefore, it is evident that all the combinations of insecticides and fungicides are physically compatible and are readily used for spraying onto the crop. Siddartha *et al*. (2014) [13] reported that chlorantraniliprole, flubendiamide, novaluron, proton, profenophos were clearly compatible with (carbendazim 12% + mancozeb 63% WP) whereas indoxacarb and chlorpyriphos + cypermethrin were incompatible with (carbendazim 12% + mancozeb 63% WP).

Table 2: Physical compatibility of insecticides and fungicides

S. No	Pesticide Combination	Sedimentation ml l^{-1}	Foaming ml l^{-1}
1	Lambda cyhalothrin 4.6% + Chlorantraniliprole 9.3% ZC + Azoxystrobin 18.2% + Difenoconazole 11.4% SC	0	0
2	Chlorantraniliprole 18.5% SC + Azoxystrobin 18.2% + Difenoconazole 11.4% SC	0	0
3	Flubendiamide 39.35% SC + Azoxystrobin 18.2% + Difenoconazole 11.4% SC	0	0
4	Azadirachtin 1500 ppm + Azoxystrobin 18.2% + Difenoconazole 11.4% SC	0	0
5	Lambda cyhalothrin 4.6%+ Chlorantraniliprole 9.3% ZC + Carbendazim 12% + Mancozeb 63% WP	15	0
6	Chlorantraniliprole 18.5% SC + Carbendazim 12% + Mancozeb 63% WP	0	0
7	Flubendiamide 39.35% SC + Carbendazim 12% + Mancozeb 63% WP	5	0
8	Azadirachtin 1500 ppm + Carbendazim 12% + Mancozeb 63% WP	0	0

The pH of test pesticides alone and in combinations was tested by using digital pH meter. The pH of all the test solutions was in the range of 5.47 to 6.78.

Among the insecticides, fungicides tested alone all the four insecticides *viz.*, lambda cyhalothrin 4.6%+ chlorantraniliprole 9.3% ZC, chlorantraniliprole 18.5% SC, flubendiamide 39.35% SC, azadirachtin 1500 ppm recorded pH values 6.48, 6.18, 6.17 and 6.06 respectively, are slightly acidic, fungicides *i.e.*, azoxystrobin 18.2% + difenoconazole 11.4% SC (pH - 6.06) is slightly acidic, carbendazim 12% + mancozeb 63% WP (pH - 5.59) is strongly acidic.

Out of all the combinations (lambda cyhalothrin 4.6%+ chlorantraniliprole 9.3% ZC) + (carbendazim 12% + mancozeb 63% WP) was strongly acidic with pH of 5.47. Chlorantraniliprole 18.5% SC + (carbendazim 12% + mancozeb 63% WP) was moderately acidic with pH of 5.78. Flubendiamide 39.35% SC + (carbendazim 12% + mancozeb 63% WP), azadirachtin 1500 ppm + (carbendazim 12% + mancozeb 63% WP), (lambda cyhalothrin 4.6%+ chlorantraniliprole 9.3% ZC) + (azoxystrobin 18.2% + difenoconazole 11.4% SC), flubendiamide 39.35% SC + (azoxystrobin 18.2% + difenoconazole 11.4% SC) were slightly acidic with pH of 6.14, 6.21, 6.50, 6.54 respectively. Chlorantraniliprole 18.5% SC + (azoxystrobin 18.2% + difenoconazole 11.4% SC), azadirachtin 1500 ppm + (azoxystrobin 18.2% + difenoconazole 11.4% SC) were neutral with pH of 6.78 and 6.77 pH respectively.

Phytotoxicity symptoms were observed only at 3 days after 1st spraying. The per cent injury calculated was below 1.0 per cent at 3 DAS which reveals that the combinations did not produced phytotoxicity symptoms based on the phytotoxicity visual rating scale explained under chapter III. Therefore, from the above results it is evident that all the combinations are compatible at their recommended doses. Present findings were in accordance with earlier reports of Kubendran *et al.* (2009) [5] reported that flubendiamide in combination with fungicide, micro and macro nutrients at different concentrations did not show any phytotoxic symptoms like chlorosis, necrosis, wilting, leaf tip injury, epinasty on leaves, capsules on cardamom plants.

Table 3: Classification of pesticides alone and in combination based on pH range.

S. No	Nature	pH range	Pesticides
1	Strongly acidic	5.1-5.5	• Lambda cyhalothrin 4.6%+ Chlorantraniliprole 9.3% ZC + Carbendazim 12% + Mancozeb 63% WP • Carbendazim 12% + Mancozeb 63% WP
2	Moderately acidic	5.6-6.0	• Chlorantraniliprole 18.5% SC + Carbendazim 12% + Mancozeb 63% WP
3	Slightly acidic	6.1-6.5	• Azadirachtin 1500 ppm • Azoxystrobin 18.2% + Difenoconazole 11.4% SC • Flubendiamide 39.35% SC + Carbendazim 12% + Mancozeb 63% WP • Flubendiamide 39.35% SC • Chlorantraniliprole 18.5% SC • Azadirachtin 1500 ppm + Carbendazim 12% + Mancozeb 63% WP • Lambda cyhalothrin 4.6% + Chlorantraniliprole 9.3% ZC • Lambda cyhalothrin 4.6% + Chlorantraniliprole 9.3% ZC + Azoxystrobin 18.2% + Difenoconazole 11.4% SC • Flubendiamide 39.35% SC + Azoxystrobin 18.2% + Difenoconazole 11.4% SC
4	Neutral	6.6-7.3	• Azadirachtin 1500 ppm + Azoxystrobin 18.2% + Difenoconazole 11.4% SC • Chlorantraniliprole 18.5% SC + Azoxystrobin 18.2% + Difenoconazole 11.4% SC

Table 4: Phytotoxic effects of pesticide combinations on maize plants at 3 DAS after 1st spraying

S. No	Pesticide combination	CLM	R	WL	S	N	W	WP
1	Lambda cyhalothrin 4.6% + Chlorantraniliprole 9.3% ZC + Azoxystrobin 18.2% + Difenoconazole 11.4% SC	0	0	0	0	0	0	0
2	Chlorantraniliprole 18.5% SC + Azoxystrobin 18.2% + Difenoconazole 11.4% SC	0	0	0	0	0	0	0
3	Flubendiamide 39.35% SC + Azoxystrobin 18.2% + Difenoconazole 11.4% SC	0	0	0	0	0.23	0	0
4	Azadirachtin 1500 ppm + Azoxystrobin 18.2% + Difenoconazole 11.4% SC	0	0	0	0	0	0	0
5	Lambda cyhalothrin 4.6%+ Chlorantraniliprole 9.3% ZC + Carbendazim 12% + Mancozeb 63% WP	0	0	0	0	0.10	0	0
6	Chlorantraniliprole 18.5% SC + Carbendazim 12% + Mancozeb 63% WP	0	0	0	0	0	0	0
7	Flubendiamide 39.35% SC + Carbendazim 12% + Mancozeb 63% WP	0	0	0	0	0.35	0	0
8	Azadirachtin 1500 ppm + Carbendazim 12% + Mancozeb 63% WP	0	0	0	0	0	0	0

CLM = Chlorotic leaf margins, **R** = Reddish or purplish veins, **WL** = Wrinkled leaves, **S** = Stunted growth, **N** = Necrosis, **W** = Wilting, **WP** = Whiplashing, **DAS =** Days After Spraying.

4. Conclusion

At 60 minutes after the jar test out of 8 combinations lambda cyhalothrin 4.6%+ chlorantraniliprole 9.3% ZC + carbendazim 12% + mancozeb 63% WP, flubendiamide 39.35% SC + carbendazim 12% + mancozeb 63% WP registered 15 ml l^{-1} and 5 ml l^{-1} respectively which was less than the limits of 2ml/ 100 ml as specified by ISI. Hence, all the combinations were treated as physically compatible. Out of all the pesticidal solutions carbendazim 12% + mancozeb 63% WP, lambda cyhalothrin 4.6%+ chlorantraniliprole 9.3% ZC + carbendazim 12% + mancozeb 63% WP were strongly acidic and remaining are near to neutral.

The percent injury calculated was below 1.0 percent which shows that the combinations did not produced phytotoxicity symptoms on the basis of phytotoxicity scale revealing that all the combinations are compatible biologically.

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