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Bioefficacy studies of compatible combinations of different agrochemicals in cotton

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Abstract
Five commonly used insecticides (contact and systemic), two fungicides, one chemical and two fertilizers in forty combinations were tested at their recommended doses for its physical, chemical compatibility, phytotoxicity and bio efficacy on cotton crop at Regional Agricultural Research Station, Nandyal during Kharif, 2016-17. All the agro chemicals tested were physically and chemically compatible. In all the 42 combinations, though there was no much change in p^H values of individual chemicals and in combination with other chemicals, the EC values of KNO_3 and its combination with other chemicals were higher. Phytotoxicity symptoms such as leaf epinasty, leaf hyponasty, necrosis and scorching were not observed in all the combinations tested. Among the combinations, thiamethoxam alone, Flonicamid + urea, Flonicamid + propiconazole, thiamethoxam + urea and monocrotophos + KNO_3 reduced the leafhoppers population by 55.73, 55.05, 54.17, 53.77 and 53.71% after 3 days after the spray. However, Flonicamid + urea and Flonicamid + propiconazole continued to show their efficacy even after 5 days after spray by recording 35.86 and 33.08 % reduction in leafhopper population.

Keywords: cotton, leafhoppers, compatibility, insecticides, fertilizers

Introduction
Cotton (*Gossypium hirsutum* L.), popularly known as "white gold" is an important fibre and cash crop of India having global significance. Cotton being a long duration and succulent crop, it is infested by a number of insect pests throughout its growth period. In India, about 162 insect pest species attack cotton crop from sowing to harvesting and causes yield loss up to 50-60 per cent [1]. The insect pests of cotton can be primarily divided into two groups as sucking pests and bollworms. Aphid (*Aphis gossypii* Glover), jassids (*Amrasca biguttula biguttula* Ishida), thrips (*Thrips tabaci* Lind.) and whitefly (*Bemisia tabaci* Genn.) are the major sucking pests of cotton. These sucking pests are noticed at all the stages of crop growth and responsible for direct and indirect yield losses. A reduction of 22.85 per cent in seed cotton yield due to sucking pests has been reported by [2, 3]. According to [4], *Bt* cotton succumb to yield loss due to sucking pests such as leafhoppers, aphids, thrips and whitefly, etc. At the same time various diseases are also casuing economical loses in cotton cultivation. For effective management of the insect pests and diseases requires frequent applications of chemcial sprays which increases the cost of cultirvation. In general farmers apply insecticides and fungicides together for the control of insect pests and diseases to reduce the cost of plant protection. Mixture of two pesticides may produce greater insecticidal action than the sum of the individual components by synergism [5]. It has been proposed that pesticide mixtures may delay the onset of resistance developing in pest populations [6]. The numbers of chemicals involved in plant protection are too many and the information on compatibility of individual chemical is scanty. Common growers facing difficulty in ascertaining the compatibility of agro-chemicals. Hence, based on experience, [7] prepared a chart showing compatibility of some insecticides and fungicides. Later several charts were developed or updated by [8, 9] for the chemicals in use with additional information regarding compatibility in different crops, season, aging of mixtures and many other factors.

It has been reported that diafenthiuron in combination with carbendazim and copper oxychloride were found to be more effective in reducing the sucking pest population and foliar diseases incidence in cotton [10]. It is a common practice of farmers to use pesticides and their mixtures most frequently without consideration of compatibility and efficacy. The information available on novel insecticides in combination with fungicides that are commonly used by farmers against insect pests and diseases is very scare.

If compatible insecticides and fungicides mixture is used in combination it may prove cheaper and such combination become useful for the control of both insect pests and diseases without losing their efficacy individually. Keeping this in mind present study was carried out to evaluate compatibility of different pesticides against sucking pests *viz*; leafhoppers and whiteflies of cotton and to find out most cost effective pesticidal treatment.

Materials and Methods

The experiment was conducted at Regional agricultural Research Station, Nandyal in *Kharif*, 2016-17 by taking RCH 2 BGII cotton hybrid as test hybrid and the crop was raised following all the recommended package of practices except plant protection. Agrochemicals (5 insecticides, *viz*., Monocrotophos, Imidacloprid , flonicamid, thiamethoxam and acephate; two fungicides *viz*., (copper oxy chloride and propiconazole), one chemical (Cobalt chloride) and fertilizers (KNO_3 and Urea) were tested at recommended doses and arrived at a total of 42 combinations which were tested for their physical and chemical compatibility following standard procedures**.** At first for all the individual chemicals and their combinations, p^H and EC were calculated. For testing physical compatibility, clear glass jars with lids (250 ml capacity) were taken with 100 ml water and to this added the test insecticides/ fungicides (undiluted chemical as per dilution factor) in the order of WP-WG-SC-SP- SL. The mixtures were stirred after each addition and capped the jars tightly with lids and turn the jars 10 times and left aside for 5 Minutes. Finally observed for incompatible phenomena (flakes/precipitate/gel/slurry/layering, etc.). Among the combinations, physically compatible combinations were tested for their phytotoxicity at field level at flowering stage of the crop and recorded the phytotoxicity score using 0-9 scale.

Phytotoxicity scale

Observations on phytotoxity were recorded at a day before, 3 and 5 days after spray. Observation for the specific parameters like leaf tip & surface injury, hyponasty and epinasty and scorching were recorded by using following scale. Safe combinations with zero phytotoxicity ratings were studied for bio-efficacy against the leafhoppers of cotton Observations on the incidence of leafhoppers were made as per the standard protocols (on three leaves, one each from top, middle and bottom canopy of the plant) at a day before and at 3^{rd} and 5^{th} day after spraying. The reduction over pre-treatment count was calculated and expressed as percentage.

Phytotoxicity rating scale

S. No	Crop Response / Crop injury	Rating
1	0-00	0
2	1-10 %	1
3	11-20%	2
4	21-30%	3
5	31-40%	4
6	41-50%	5
7	51-60%	6
8	61-70%	7
9	71-80%	8
10	81-90%	9
11	91-100%	10

Results and Discussion

Compatibility

All the treatment combinations were tested for their physical and chemical compatibility and all the treatments were found compatible both physically and chemically. The p^H and EC of individual chemicals and their combinations are given in Table 2. The p^H value of different chemicals ranged from 7.03 to 7.85 indicating that they are all alkaline and safe to use on plants. The EC values of individual chemicals was below one except for KNO_3 and its combination with other chemicals wherein the EC was above eight. The chemicals and their combinations were found compatible without any flocculation, sedimants, leaf epinasty, leaf hyponasty, necrosis and phytotoxicity (Table 3).

Bio efficacy

A day before spray, the population of leafhoppers ranged from 7.20 to 10.07 leafhoppers / 3 leaves (Table 4). At 3 days after spray, the leafhopper population ranged from 3.72 (flonicamid + imidacloprid) to 4.49 (imidacloprid, flonicamid + KNO_3) indicating the efficacy of chemicals and their combinations. Even after 5 days, the treatments were effective in reducing the leafhopper population and the population of leafhoppers ranged from 5.72 (flonicamid + imidacloprid) to 6.51 (monocrotophos + KNO_3). The per cent reduction over pre-treatment count of different combinations was presented in table 4. The per cent reduction over pre-treatment count at 3 days after spray ranged from 45.94 (monocrotophos + Copper oxy chloride) to 55.73% (thiamethoxam). The treatment combinations flonicamid + urea (55.05%), thiamethoxam + urea (53.77 %) and monocrotophos + KNO_3 (53.71%) are the next best treatments. At 5 days after spray, tiamerthoxam, flonicamid + urea and flonicamid + propiconazole were best by recording 35.86, 35.05 and 33.48 % reduction of leafhoppers over pre-treatment count. The lowest % reduction of leafhoppers (18.41%) was recorded in monocrotophos + copper oxychloride). The list of best and effective combinations against leafhoppers in cotton is given in Table 5.

The results of the present investigation i.e., thiamethoxam and flonicamid +urea which gave 55.73 and 55.05% reduction of leafhoppers were in agreement with the findings of [15] who reported the efficacy of thiamethoxam against leafhoppers under laboratory conditions and the investigations of [12] also supports the results of present investigation that flonicamid alone and in combination with other chemicals gave good reduction of leafhoppers in cotton. Moreover, the earlier workers [10] reported that diafenthiuron 50% WP when sprayed in combination with copper oxychloride 50 WP exhibited additive action, and was very effective against

cotton leafhoppers. Similarly, [14] reported an enhanced action of combination of spiromesifen and fipronil against leafhoppers in cotton.

Table 1: Compatibility chart for Insecticides Vs Fungicides Vs fertilizers

Agrochemicals	Monocrotophos	Imidacloprid	Flonicamid	Thiamethoxam	Acephate	Copper oxychloride	Propiconazole	Cobalt Chloride	K NO3	Urea
Monocrotophos	C	C	C	C	C	C	C	C	C	C
Imidacloprid		C	C	C	C	C	C	C	C	C
Flonicamid			C	C	C	C	C	C	C	C
Thiamethoxam				C	C	C	C	C	C	C
Acephate					C	C	C	C	C	C
Copper oxychloride						C	C	C	C	C
Propiconazole							C	C	C	C
Cobalt Chloride								C	C	C
K NO3									C	C
Urea										C

Table 2: p^H and EC of individual and combinations of insecticides, fungicides and fertilizers used on cotton

S. No.	Treatment name	pH	EC
1	Flonicamid	7.36	0.64
2	Monocrotophos	7.16	0.63
3	Imidacloprid	7.76	0.67
4	Thiamethoxam	7.68	0.77
5	urea	7.83	0.75
6	Acephate	7.42	0.83
7	Copper oxy chloride	7.25	0.77
8	Propiconazole	7.24	0.77
9	Cobalt chloride	7.18	0.77
10	KNO_3	7.86	8.36
11	Flonicamid+Monocrotophos	7.06	0.65
12	Flonicamid+Imidacloprid	7.35	0.76
13	Flonicamid+Thiamethoxam	7.20	0.78
14	Flonicamid+urea	7.33	0.79
15	Flonicamid+Acephate	7.12	0.82
16	Flonicamid+ Copper oxy chloride	7.23	0.76
17	Flonicamid+Propiconazole	7.26	0.71
18	Flonicamid+ KNO_3	7.28	8.23
19	Flonicamid+cobalt chloride	7.37	1.08
20	Monocrotophos+Imidacloprid	7.03	0.76
21	Monocrotophos+Thiamethoxam	7.14	0.69
22	Monocrotophos+urea	7.16	0.76
23	Monocrotophos+Acephate	7.03	0.82
24	Monocrotophos+Copperoxy chloride	7.06	0.74
25	Monocrotophos+Propiconazole	7.10	0.68
26	Monocrotophos+cobalt chloride	7.06	0.92
27	Monocrotophos+ KNO_3	7.12	8.46
28	Imidacloprid+Actar	7.22	0.71
29	Imidacloprid+Urea	7.18	0.75
30	Imidacloprid+Acephate	7.12	0.81
31	Imidacloprid+ Copper oxy chloride	7.23	0.81
32	Imidacloprid+Propiconazole	7.21	0.78
33	Imidacloprid+cobalt chloride	7.16	1.04
34	Imidacloprid+ KNO_3	7.26	8.52
35	Thiamethoxam +urea	7.24	0.78
36	Thiamethoxam +Acephate	7.13	0.9
37	Thiamethoxam + Copper oxy chloride	7.08	0.76
38	Thiamethoxam +Propiconazole	7.13	0.64
39	Thiamethoxam +cobalt chloride	7.32	0.98
40	Acephate+urea	7.01	1.05
41	Acephate+ Copper oxy chloride	7.09	0.83
42	Acephate+Propiconazole	7.08	0.81

Table 3: Combinations of insecticides, fungicides and fertilizers used on cotton for their phytotoxicity studies

Tr. No.	Treatment combination	Leaf epinasty	Leaf hyponasty	Necrosis	Scorching
T1	Flonicamid	Not found	Not found	Not found	Not found
T2	Monocrotophos	Not found	Not found	Not found	Not found
T3	Imidacloprid	Not found	Not found	Not found	Not found
T4	Thiamethoxam	Not found	Not found	Not found	Not found
T5	urea	Not found	Not found	Not found	Not found
T6	Acephate	Not found	Not found	Not found	Not found
T7	Copper oxy chloride	Not found	Not found	Not found	Not found
T8	Propiconazole	Not found	Not found	Not found	Not found
T9	Cobalt chloride	Not found	Not found	Not found	Not found
T10	KNO_3	Not found	Not found	Not found	Not found
T11	Flonicamid+Monocrotophos	Not found	Not found	Not found	Not found
T12	Flonicamid+Imidacloprid	Not found	Not found	Not found	Not found
T13	Flonicamid+Thiamethoxam	Not found	Not found	Not found	Not found
T14	Flonicamid+urea	Not found	Not found	Not found	Not found
T15	Flonicamid+Acephate	Not found	Not found	Not found	Not found
T16	Flonicamid+ Copper oxy chloride	Not found	Not found	Not found	Not found
T17	Flonicamid+Propiconazole	Not found	Not found	Not found	Not found
T18	Flonicamid+ KNO_3	Not found	Not found	Not found	Not found
T19	Flonicamid+cobalt chloride	Not found	Not found	Not found	Not found
T20	Monocrotophos+Imidacloprid	Not found	Not found	Not found	Not found
T21	Monocrotophos+Thiamethoxam	Not found	Not found	Not found	Not found
T22	Monocrotophos+urea	Not found	Not found	Not found	Not found
T23	Monocrotophos+Acephate	Not found	Not found	Not found	Not found
T24	Monocrotophos+Copperoxychloride	Not found	Not found	Not found	Not found
T25	Monocrotophos+Propiconazole	Not found	Not found	Not found	Not found
T26	Monocrotophos+cobalt chloride	Not found	Not found	Not found	Not found
T27	Monocrotophos+ KNO_3	Not found	Not found	Not found	Not found
T28	Imidacloprid+Actar	Not found	Not found	Not found	Not found
T29	Imidacloprid+Urea	Not found	Not found	Not found	Not found
T30	Imidacloprid+Acephate	Not found	Not found	Not found	Not found
T31	Imidacloprid+ Copper oxy chloride	Not found	Not found	Not found	Not found
T32	Imidacloprid+Propiconazole	Not found	Not found	Not found	Not found
T33	Imidacloprid+cobalt chloride	Not found	Not found	Not found	Not found
T34	Imidacloprid+ KNO_3	Not found	Not found	Not found	Not found
T35	Thiamethoxam +urea	Not found	Not found	Not found	Not found
T36	Thiamethoxam +Acephate	Not found	Not found	Not found	Not found
T37	Thiamethoxam+Copperoxychloride	Not found	Not found	Not found	Not found
T38	Thiamethoxam +Propiconazole	Not found	Not found	Not found	Not found
T39	Thiamethoxam +cobalt chloride	Not found	Not found	Not found	Not found
T40	Acephate+urea	Not found	Not found	Not found	Not found
T41	Acephate+ Copper oxy chloride	Not found	Not found	Not found	Not found
T42	Acephate+Propiconazole	Not found	Not found	Not found	Not found

Table 4: Efficacy of different treatment combinations against leafhoppers of cotton

S. No	Treatment name	DBS	3DAS	% reduction	5DAS	% reduction
1	Flonicamid	7.40	3.99	46.11	5.99	19.08
2	Monocrotophos	8.13	4.18	48.63	6.18	24.04
3	Imidacloprid	9.53	4.49	52.90	6.49	31.92
4	Thiamethoxam	10.07	4.46	55.73	6.46	35.86
5	Urea	8.47	4.35	48.58	6.35	24.96
6	Acephate	8.60	4.32	49.71	6.32	26.46
7	Copper oxy chloride	8.20	4.18	48.99	6.18	24.60
8	propiconazole	8.67	4.16	52.03	6.16	28.96
9	cobalt chloride	7.93	4.00	49.56	6.00	24.35
10	KNo3	9.27	4.41	52.36	6.41	30.78
11	Flonicamid+Monocrotophos	8.40	4.12	50.99	6.12	27.18
12	Flonicamid+Imidacloprid	7.20	3.72	48.31	5.72	20.53
13	Flonicamid+ Thiamethoxam	8.27	4.16	49.63	6.16	25.44
14	Flonicamid+urea	10.00	4.50	55.05	6.50	35.05
15	Flonicamid+Acephate	8.27	4.29	48.04	6.29	23.85
16	Flonicamid+Copper oxy chloride	7.40	3.90	47.33	5.90	20.30
17	Flonicamid+Propiconazole	9.67	4.43	54.17	6.43	33.48
18	Flonicamid+ KNO_3	9.33	4.49	51.90	6.49	30.48
19	Flonicamid+cobalt chloride	8.20	4.23	48.45	6.23	24.06
20	Monocrotophos+Imidacloprid	8.33	4.01	51.84	6.01	27.84

21	Monocrotophos+ Thiamethoxam	8.00	4.12	48.54	6.12	23.54
22	Monocrotophos+urea	8.80	4.33	50.79	6.33	28.06
23	Monocrotophos+Acephate	8.87	4.28	51.76	6.28	29.21
24	Monocrotophos+Copper oxy chloride	7.27	3.93	45.94	5.93	18.41
25	Monocrotophos+Propiconazole	7.87	4.09	47.96	6.09	22.54
26	Monocrotophos+cobalt chloride	9.00	4.33	51.90	6.33	29.68
27	Monocrotophos+ KNO_3	9.73	4.51	53.71	6.51	33.17
28	Imidacloprid+Actar	8.53	4.16	51.21	6.16	27.77
29	Imidacloprid+Urea	7.47	4.02	46.11	6.02	19.33
30	Imidacloprid+Acephate	8.93	4.17	53.34	6.17	30.95
31	Imidacloprid+ Copper oxy chloride	8.87	4.40	50.35	6.40	27.79
32	Imidacloprid+Propiconazole	9.13	4.29	53.04	6.29	31.14
33	Imidacloprid+cobalt chloride	8.67	4.32	50.19	6.32	27.11
34	Imidacloprid+ KNO_3	7.87	4.11	47.75	6.11	22.32
35	Thiamethoxam +urea	9.47	4.38	53.77	6.38	32.64
36	Thiamethoxam +Acephate	9.07	4.34	52.09	6.34	30.03
37	Thiamethoxam + Copper oxy chloride	8.53	4.30	49.66	6.30	26.22
38	Thiamethoxam +Propiconazole	8.67	4.25	50.91	6.25	27.84
39	Thiamethoxam +cobalt chloride	8.93	4.28	52.07	6.28	29.69
40	Acephate+urea	9.00	4.33	51.88	6.33	29.66
41	Acephate+ Copper oxy chloride	8.67	4.15	52.10	6.15	29.03
42	Acephate+Propiconazole	7.40	3.88	47.50	5.88	20.48

DBS-Day before spray DAS- Day after spray

Table 5: List of best combinations of insecticides, fungicides and fertilizers which gave 50% reduction in leafhoppers population in cotton at 3 DAS

Treatment combination	% reduction
Thiamethoxam	55.73
Flonicamid+urea	55.05
Flonicamid+Propiconazole	54.17
Thiamethoxam+urea	53.77
Monocrotophos+ KNO_3	53.71
Imidacloprid+Acephate	53.34
Imidacloprid+Propiconazole	53.04
Imidacloprid	52.90
Acephate+ Copper oxy chloride	52.10
Thiamethoxam+Acephate	52.09
Thiamethoxam+cobalt chloride	52.07
Monocrotophos+cobalt chloride	51.90
Flonicamid+KNO_3	51.90
Acephate+urea	51.88
Monocrotophos+Imidacloprid	51.84
Monocrotophos+Acephate	51.76
Imidacloprid+thiamethoxam	51.21
Flonicamid+Monocrotophos	50.99
Thiamethoxam+Propiconazole	50.91
Monocrotophos+urea	50.79
Imidacloprid+ Copper oxy chloride	50.35
Imidacloprid+cobalt chloride	50.19

Conclusion

Among the 42 combinations tested on cotton, all the combinations were physically as well as chemically compatible. The bio efficacy studies of all compatible agrochemical combinations in cotton against leafhoppers indicated that, thiamethoxam and flonicamid alone, the combinations like flonicamid +imidacloprid, Monocrotophos + copper oxychloride and acephate +propiconazole were effective against leafhoppers in cotton.

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