



COMPATIBILITY OF INSECTICIDE AND FUNGICIDE MIXTURES AGAINST *SPODOPTERA LITURA* (F.) ON VIRGINIA TOBACCO

B. SAILAJA JAYASEKHARAN*, U. SREEDHAR AND G. RAGHUPATHI RAO

Division of Crop Protection, ICAR-Central Tobacco Research Institute, Rajahmundry 533105

*Email: sailaja8489@gmail.com

ABSTRACT

Evaluation of the efficacy and compatibility of certain new insecticides with fungicides alone and in combination as mixtures against *Spodoptera litura* (F.) on flue cured Virginia (FCV) tobacco was done. Results revealed that chlorfenapyr 10 SC @0.01% and chlorantraniliprole 18.5 SC @0.055% were the most effective. In combination with the fungicides too, chlorfenapyr 10 SC @0.01% was the best demonstrating compatibility. Among the two anthranilic diamides, chlorantraniliprole 18.5 SC @0.005% revealed compatibility with certain fungicides, whereas flubendiamide 48 SC @ 0.012% was observed with reduced efficacy in almost all combinations. Even though, with regard to the physical properties and p^H all the combination treatments were stable even after two hours of preparation, their efficacy got slightly reduced except with chlorfenapyr 10 SC @0.01% and chlorantraniliprole 18.5 SC @0.005%.

Key words: *Spodoptera litura*, tobacco, compatibility, insecticides, fungicides, chlorfenapyr, chlorantraniliprole, flubendiamide, physical properties, p^H

Application of pesticide mixtures is becoming common and farmers often mix insecticides and fungicides to save time, labour and energy. Such mixing saves expenditure provided there are no adverse effects on the plant and non target organisms. Compatibility charts are available for the agricultural chemicals in developed countries with additional information regarding incompatibility under certain crops, season, aging of mixtures and many other factors (Baicu, 1980). New insecticide formulations are available in the Indian market, but many of these lack details for their compatibility. Many studies deliberate on the compatibility of insecticide fungicide combinations against fungal diseases (Reddi Kumar et al., 2014; Suneel Kumar et al., 2016). But such details with regard to new insecticide and fungicides combinations against insect pests are meagre. Hence, the present study on the evaluation of the efficacy of insecticide fungicide combinations against tobacco caterpillar *Spodoptera litura* (F.) to advise the tobacco farmers.

MATERIALS AND METHODS

Experiments were conducted during 2016-2017 at the ICAR- Central Tobacco Research Institute, Rajahmundry on Virginia tobacco. The treatments included some new insecticides, fungicides and their mixtures viz., flubendiamide 48 SC @ 0.012%, chlorantraniliprole 18.5 SC @ 0.005%, chlorfenapyr

10 SC @ 0.010%, copper oxychloride 50 WP @ 0.2%, carbendazim 50 WP @ 0.03%, pyraclostrobin+ metiram 60 WG @ 0.2%, metalaxyl+ mancozeb 68 WP @ 0.2%, fenamidon+ mancozeb 60 WG @ 0.3% and azoxystrobin 23 SC @ 0.1%. Recommended doses of insecticides and fungicides were used (combination treatments - 1:1 proportion) taking distilled water as control. Wettable powder (WP), dry flowable (DF) or water-dispersible granules (WDG) were added first, followed by emulsifiable concentrates (EC), solution (S) or soluble powder (SP) products as recommended in the pesticide applicator manual (Anonymous, 1999). Dry formulations were preslurried (mixed with a little water) before adding them to leaf dipping solution. The toxicity of insecticide fungicide combinations and individual insecticides was quantified with leaf dip bioassay method. Fresh and uniform sized tobacco leaves were dipped in insecticide fungicide combination solutions for 30 sec and dried at room temperature. Ten early third instar larvae of *S. litura* were released on treated leaves in each petri dish maintained in room temperature and mortality observed at 24 and 48 hr treatment (HAT). These observed data were converted to %, and then subjected to Abbott's (1925) correction.

Jar compatibility test was conducted by mixing 500 ml each of insecticide and fungicide solutions, to evaluate their physical compatibility- colour, wettability,

clumping or precipitate formation were observed along with pH of the solutions at 0.5 and 2 hr after preparation. To evaluate the mixtures' potential to cause leaf injury, the treatments were also evaluated for their phytotoxicity on tobacco plants at the ICAR-CTRI Black Soil Research Farm, Katheru. One litre each of the recommended dose of an insecticide and a fungicide were mixed well in a tub before pouring into spray tank and sprayed. Observations on 1, 3, 7, 9, 11 and 14 days after spray were made on symptoms- 1. Leaf tip and surface injury, 2. Wilting, 3. Vein clearing, 4. Necrosis, 5. Epinasty, 6. Hyponasty, with symptoms marked as respective grades. Leaf injury and phytotoxicity rating were made after Suneel Kumar et al. (2016) as follows:

$$\% \text{ leaf injury} = \frac{\text{Total grade points}}{\text{Maximum grade} \times \text{no. of leaves}} \times 100$$

Phytotoxicity grades	% leaf injury
0	Nil
1	1-10
2	11-20
3	21-30
4	31-40
5	41-50
6	51-60
7	61-70
8	71-80
9	81-90
10	91-100

RESULTS AND DISCUSSION

Insecticides and fungicides- individual efficacy:

The bioassays revealed that chlorfenapyr and chlorantraniliprole gave 100% mortality within 24 hr and were statistically on a par (Table 1); flubendiamide resulted in 63.33 and 68.41% mortality within 24 and 48 hr, respectively. Sole application of pyraclostrobin + metiram was slow in action initially at 24 hr, but registered about 93.33% mortality by 48 hr; however, it reduced the efficacy in combination with insecticides. Carbendazim gave 66.66% mortality after 48 hr after treatment, and copper oxy chloride, metalaxyl + mancozeb, fenamidon+ mancozeb and azoxystrobin resulted in 46.66, 16.66, 20.00 and 46.66% mortality, respectively.

Insecticides+ fungicides combinations' efficacy:

Except for chlorfenapyr (> 90 % mortality) other insecticides were observed to give reduced toxicity in combination with fungicides at 48 hr after treatment (Table 2). Sivalalitha (2013) too observed 100% mortality with chlorfenapyr and carbendazim combination, although at a higher dose and prolonged time of 72 hr. Despite remarkable efficacy of chlorantraniliprole when used alone, 30% reduction in efficacy was observed in combination with conventional fungicides as well as strobilurin fungicides i.e., pyraclostrobin + metiram and azoxystrobin (Table 3), except for the ones with mancozeb based fungicides (93.33% mortality). Flubendiamide had been recommended against lepidopterous pests (Gupta et al., 2004; Sharma and Pathania, 2014). In contrast the present results indicate that it is not as effective compared to the other two new insecticides. Similar results had been obtained by Krishna Kanth et al. (2016) who reported that LC₅₀ of flubendiamide was double that of chlorantraniliprole for *S. litura*. The toxicity levels of combinations of flubendiamide with copper oxychloride, fenamidon+ mancozeb and azoxystrobin were also >65%; but the combinations of flubendiamide with carbendazim, metalaxyl + mancozeb and pyraclostrobin+metiram were less effective (Table 4).

Stability and phytotoxicity: The pH, wettability and appearance of individual and combinations assessed by jar compatibility test did not vary remarkably (Table 5). The field sprays of individual as well as combinations did not show any phytotoxicity symptoms.

Thus chlorfenapyr used alone and in combination with fungicides demonstrated maximum efficacy and is highly compatible with all the fungicides evaluated. Copper oxychloride, metalaxyl + mancozeb, fenamidon + mancozeb and azoxystrobin when used alone gave <50 % mortality; but these enhanced the toxicity in their combinations with insecticides, albeit not equivalent to mortality with insecticides alone. Combinations of pyraclostrobin+ metiram and carbendazim with insecticides resulted in reduced efficacy at 48 HAT. Hence, it is safe to use insecticides and fungicides separately based on necessity, except for the combination of chlorfenapyr with all the evaluated fungicides, and chlorantraniliprole with mancozeb based fungicides.

Table 1. Efficacy of insecticides, fungicides alone and in combinations against *S.litura*

S.No.	Treatments alone	Mortality %		Treatment combinations with Chlorfenapyr 10 SC @ 0.005 % +	Mortality %		Treatment combinations with Chlorantraniliprole 18.5 SC @ 0.005 %	Mortality %		Treatment combinations with flubendiamide 48 SC @ 0.012 %	Mortality %	
		24 HAT	48 HAT		24HAT	48HAT		24HAT	48HAT		24HAT	48HAT
1.	Flubendiamide 48 SC @ 0.012 %	63.33 (52.77)b	72.41 (59.00)b	Chlorfenapyr 10 SC @ 0.005 %	100.00 (89.09)a	100.00 (89.09)a	Chlorantraniliprole 18.5 SC @ 0.005 %	100.00 (89.09)a	100.00 (89.09)a	Flubendiamide 48 SC @ 0.012 %	63.33 (52.77)a	72.41 (59.00)a
2.	Chlorantraniliprole 18.5 SC @ 0.005 %	100.00 (89.09)a	100.00 (89.09)a	Copper oxy chloride 50 WP @ 0.2 %	96.67 (83.25)a	100.00 (89.09)a	Copper oxy chloride 50 WP @ 0.2 %	33.33 (34.13)d	73.33 (59.22)c	Copper oxy chloride 50 WP @ 0.2 %	43.33 (41.15)b	65.52 (54.78)a
3.	Chlorfenapyr 10 SC @ 0.010 %	100.00 (89.09)a	100.00 (89.09)a	Carbendazim 50 WP @ 0.03 %	66.67 (54.78)b	93.33 (77.40)b	Carbendazim 50 WP @ 0.03 %	23.33 (28.07)d	70.00 (57.71)c	Carbendazim 50 WP @ 0.03 %	13.33 (21.15)d	34.48 (37.14)b
4.	Copper oxy chloride 50 WP @ 0.2 %	33.33 (35.22)c	46.66 (43.07)c	Pyraclostrobin+ Metiram 60 WG @ 0.2 %	66.67 (55.00)b	90.00 (74.69)b	Pyraclostrobin+ Metiram 60 WG @ 0.2 %	33.33 (35.22)d	70.00 (56.78)c	Pyraclostrobin+ Metiram 60 WG @ 0.2 %	6.66 (18.43)d	17.24 (26.56)c
5.	Carbendazim 50 WP @ 0.03 %	10.00 (15.30)d	66.66 (55.07)b	Metalaxyl+ Mancozeb 68 WP @ 0.2 %	96.67 (83.25)a	100.00 (89.09)a	Metalaxyl+ Mancozeb 68 WP @ 0.2 %	96.66 (83.25)ab	100.00 (89.09)a	Metalaxyl+ Mancozeb 68 WP @ 0.2 %	20.00 (26.56)c	31.03 (35.22)bc
6.	Pyraclostrobin+ Metiram 60 WG @ 0.2 %	0.00 (0.90)e	93.33 (80.54)a	Fenamidon+ Mancozeb 60 WG @ 0.3 %	93.33 (77.40)a	96.67 (83.25)ab	Fenamidon+ Mancozeb 60 WG @ 0.3 %	90.00 (74.69)b	93.33 (77.40)ab	Fenamidon+ Mancozeb 60 WG @ 0.3 %	23.33 (28.78)c	65.52 (54.78)a
7.	Metalaxyl+ Mancozeb 68 WP @ 0.2 %	6.66 (12.59)d	16.66 (23.36)d	Azoxystrobin 23 SC @ 0.1 %	96.67 (83.25)a	100.00 (89.09)a	Azoxystrobin 23 SC @ 0.1 %	60.00 (51.15)c	76.66 (65.55)bc	Azoxystrobin 23 SC @ 0.1 %	13.33 (21.14)d	68.96 (56.99)a
8.	Fenamidon+ Mancozeb 60 WG @ 0.3 %	3.33 (6.75)de	20.00 (26.07)d	Untreated control	0.00 (0.90)c	0.00 (0.90)c	Untreated control	0.00 (0.90)e	0.00 (0.90)d	Untreated control	0.00 (0.90)e	0.00 (6.75)d
9.	Azoxystrobin 23 SC @ 0.1 %	20.00 (26.56)c	46.66 (43.07)c	SEm ±	4.57	3.68	SEm ±	4.15	4.72	SEm ±	1.58	3.32
10.	Untreated control	0.00 (0.90)e	0.00 (0.90)e	CD (p<0.05)	13.28	10.68	CD (p<0.05)	12.40	14.00	CD (p<0.05)	4.80	9.87
	SEm ±	3.75	3.95									
	CD (p<0.05)	10.71	11.53									

*Values in parentheses arcsine transformed; In each column values with similar alphabet do not vary significantly (p=0.05); HAT- Hours after Treatment

Table 2. Bioefficacy of chlorfenapyr 10 SC alone and in combination with fungicides against *S.litura*

S.No.	Treatment	Mortality %	
		24 HAT	48 HAT
1.	Chlorfenapyr 10 SC @ 0.005 %	100.00 (89.09)a	100.00 (89.09)a
2.	Chlorfenapyr 10 SC @ 0.005 % + Copper oxychloride 50 WP @ 0.2 %	96.67 (83.25)a	100.00 (89.09)a
3.	Chlorfenapyr 10 SC @ 0.005 % + Carbendazim 50 WP @ 0.03 %	66.67 (54.78)b	93.33 (77.40)b
4.	Chlorfenapyr 10 SC @ 0.005 % + Pyraclostrobin+Metiram 60 WG @ 0.2 %	66.67 (55.00)b	90.00 (74.69)b
5.	Chlorfenapyr 10 SC @ 0.005 % + Metalaxyl+Mancozeb 68 WP @ 0.2 %	96.67 (83.25)a	100.00 (89.09)a
6.	Chlorfenapyr 10 SC @ 0.005 % + Fenamidon+Mancozeb 60 WG @ 0.3 %	93.33 (77.40)a	96.67 (83.25)ab
7.	Chlorfenapyr 10 SC @ 0.005 % + Azoxystrobin 23 SC @ 0.1 %	96.67 (83.25)a	100.00 (89.09)a
8.	Untreated control	0.00 (0.90)c	0.00 (0.90)c
	SEm±	4.57	3.68
	CD (p<0.05)	13.28	10.68

*Values in parentheses are sine transformed; In each column values with the similar alphabet do not vary significantly at p=0.05; HAT- Hours after Treatment

Table 3. Bioefficacy of chlorantraniliprole 18.5 SC alone and in combination with fungicides against *S.litura*

S.No.	Treatment	Mortality %	
		24 HAT	48 HAT
1.	Chlorantraniliprole 18.5 SC @ 0.005 %	100.00 (89.09)a	100.00 (89.09)a
2.	Chlorantraniliprole 18.5 SC @ 0.005 % + Copper oxychloride 50 WP @ 0.2 %	33.33 (34.13)d	73.33 (59.22)c
3.	Chlorantraniliprole 18.5 SC @ 0.005 % + Carbendazim 50 WP @ 0.03 %	23.33 (28.07)d	70.00 (57.71)c
4.	Chlorantraniliprole 18.5 SC @ 0.005 % + Pyraclostrobin+Metiram 60 WG @ 0.2 %	33.33 (35.22)d	70.00 (56.78)c
5.	Chlorantraniliprole 18.5 SC @ 0.005 % + Metalaxyl+Mancozeb 68 WP @ 0.2 %	96.66 (83.25)ab	100.00 (89.09)a
6.	Chlorantraniliprole 18.5 SC @ 0.005 % + Fenamidon+Mancozeb 60 WG @ 0.3 %	90.00 (74.69)b	93.33 (77.40)ab
7.	Chlorantraniliprole 18.5 SC @ 0.005 % + Azoxystrobin 23 SC @ 0.1 %	60.00 (51.15)c	76.66 (65.55)bc
8.	Untreated control	0.00 (0.90)e	0.00 (0.90)d
	SEm±	4.15	4.72
	CD (p<0.05)	12.40	14.00

*Values in parentheses are sine transformed; In each column values with the similar alphabet do not vary significantly at p=0.05; HAT- Hours after Treatment

Table 4. Efficacy of flubendiamide 48 SC alone and in combination with fungicides against *S.litura*

S.No.	Treatment	Mortality %	
		24 HAT	48 HAT
1.	Flubendiamide 48 SC @ 0.012 %	63.33 (52.77)a	72.41 (59.00)a
2.	Flubendiamide 48 SC @ 0.012 % + Copper oxy chloride 50 WP @ 0.2 %	43.33 (41.15)b	65.52 (54.78)a
3.	Flubendiamide 48 SC @ 0.012 % + Carbendazim 50 WP @ 0.03 %	13.33 (21.15)d	34.48 (37.14)b
4.	Flubendiamide 48 SC @ 0.012 % + Pyraclostrobin+Metiram 60 WG @ 0.2 %	6.66 (18.43)d	17.24 (26.56)c
5.	Flubendiamide 48 SC @ 0.012 % + Metalaxyl+Mancozeb 68 WP @ 0.2 %	20.00 (26.56)c	31.03 (35.22)bc
6.	Flubendiamide 48 SC @ 0.012 % + Fenamidon+Mancozeb 60 WG @ 0.3 %	23.33 (28.78)c	65.52 (54.78)a
7.	Flubendiamide 48 SC @ 0.012 % + Azoxystrobin 23 SC @ 0.1 %	13.33 (21.14)d	68.96 (56.99)a
8.	Untreated control	0.00 (0.90)e	0.00 (6.75)d
	SEm±	1.58	3.32
	CD (p<0.05)	4.80	9.87

*Values in parentheses are sine transformed; In each column values with the similar alphabet do not vary significantly at p=0.05; HAT- Hours after Treatment

Table 5. Physical properties and p^H of insecticides, fungicides and their combinations

S.No.	Treatments	Colour	p ^H (30 min)	p ^H (2 hr)	Wettability	Other parameters
1.	Flubendiamide 48 SC	White	7.31	7.51	Readily Soluble	No clumps
2.	Chlorantraniliprole 18.5 SC	White	7.08	7.20	Readily Soluble	No clumps
3.	Chlorfenapyr 10 SC	White	7.13	7.41	Readily Soluble	No clumps
4.	Copper oxychloride 50 WP	Green	7.21	7.31	Soluble after vigorous stirring	Slight precipitate
5.	Carbendazim 50 WP	White	7.15	7.25	Soluble after vigorous stirring	Slight precipitate
6.	Pyraclostrobin + Metiram 60 WG	Brown	7.20	7.26	Readily soluble	No clumps
7.	Metalaxyl + Mancozeb 68 WP	Yellow	7.30	7.36	Readily soluble	No clumps
8.	Fenamidon + Mancozeb 60 WG	Yellow	7.29	7.33	Readily soluble	No clumps
9.	Azoxystrobin 23 SC	White	7.16	7.30	Readily soluble	No clumps
10.	Flubendiamide 48 SC + Copper Oxychloride 50 WP	Green	7.09	7.33	Readily soluble	No clumps
11.	Flubendiamide 48 SC + Carbendazim 50 WP	White	7.15	7.29	Readily soluble	No clumps
12.	Flubendiamide 48 SC + Pyraclostrobin+Metiram 60 WG	Brown	7.17	7.37	Readily soluble	No clumps
13.	Flubendiamide 48 SC + Metalaxyl+Mancozeb 68 WP	Yellow	7.17	7.34	Readily soluble	No clumps
14.	Flubendiamide 48 SC + Fenamidon+Mancozeb 60 WG	Yellow	7.15	7.36	Readily soluble	No clumps
15.	Flubendiamide 48 SC + Azoxystrobin 23 SC	White	7.12	7.28	Readily soluble	No clumps
16.	Chlorantraniliprole 18.5 SC + Copper Oxychloride 50 WP	Green	7.20	7.28	Readily soluble	No clumps
17.	Chlorantraniliprole 18.5 SC + Carbendazim 50 WP	White	7.10	7.25	Readily soluble	No clumps
18.	Chlorantraniliprole 18.5 SC + Pyraclostrobin+Metiram 60 WG	Brown	7.17	7.27	Readily soluble	No clumps
19.	Chlorantraniliprole 18.5 SC + Metalaxyl+Mancozeb 68 WP	Yellow	7.20	7.28	Readily soluble	No clumps
20.	Chlorantraniliprole 18.5 SC + Fenamidon+Mancozeb 60 WG	Yellow	7.22	7.27	Readily soluble	No clumps
21.	Chlorantraniliprole 18.5 SC + Azoxystrobin 23 SC	White	7.19	7.43	Readily soluble	No clumps
22.	Chlorfenapyr 10 SC + Copper Oxychloride 50 WP	Green	6.98	6.95	Readily soluble	No clumps
23.	Chlorfenapyr 10 SC + Carbendazim 50 WP	White	7.19	7.17	Readily soluble	No clumps
24.	Chlorfenapyr 10 SC + Pyraclostrobin+Metiram 60 WG	Brown	7.72	7.91	Readily soluble	No clumps
25.	Chlorfenapyr 10 SC + Metalaxyl+Mancozeb 68 WP	Yellow	8.02	7.89	Readily soluble	No clumps
26.	Chlorfenapyr 10 SC + Fenamidon+Mancozeb 60 WG	yellow	7.83	7.77	Readily soluble	No clumps
27.	Chlorfenapyr 10 SC + Azoxystrobin 23 SC	white	6.84	7.03	Readily soluble	No clumps

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