The Pharma Innovation Journal 2021; SP-10(7): 621-627

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2021; SP-10(7): 621-627

www.thepharmajournal.com
Received: 04-05-2021
Accepted: 06-06-2021

Bio-efficacy of newer insecticides against sucking insect pest complex of groundnut (*Arachis hypogea* L.)

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Abstract
Efficacy of nine insecticides *viz*., thiamethoxam @ 0.4 g l^{-1}, thiacloprid @ 0.25 ml l^{-1}, flonicamid @ 0.4 g l^{-1}, pymetrozine @ 0.6 g l^{-1}, dinotefuran @ 0.3 g l^{-1}, spinosad @ 0.3 ml l^{-1}, imidacloprid @ 0.3 ml l^{-1}, acetamiprid+fipronil @ 2.0 ml l^{-1} and fipronil @ 2 ml l^{-1} against sucking insect pest complex *viz.*, leafhoppers, aphids and thrips in groundnut crop was evaluated at field level and the results revealed that all the insecticides were effective when compared with the control in reducing the population of sucking insect pest complex of groundnut. After two rounds of sprays, acetamiprid+fipronil @ 2.0 ml l^{-1} recorded significantly highest per cent reduction over control (73.58%) for sucking insect pest complex under study. The next effective treatments were, imidacloprid @ 0.3 ml l^{-1} and pymetrozine @ 0.6 g l^{-1} for leafhoppers and aphids and fipronil @ 2 ml l^{-1} for thrips. Thiamethoxam @ 0.4 g l^{-1}, flonicamid @ 0.4 g l^{-1} and dinotefuran @ 0.3 g l^{-1} exhibited moderate efficacy against the sucking insect pest complex. The least effective treatments were spinosad @ 0.3 ml l^{-1} and thiacloprid @ 0.25 ml l^{-1}.

Keywords: groundnut**,** aphids, leafhoppers, thrips, sucking pests

Introduction
Groundnut (*Arachis hypogaea* L.,) is an important oilseed crop of tropical and subtropical regions of the world. China is the leading producer with 17.3 metric tonnes (Food and Agriculture organization, 2018) [10] followed by India and USA. In India, groundnut occupies an area of 4888 million hectares with a production of 9253 million tonnes and productivity of 1893 kg ha^{-1}, respectively (Ministry of Agriculture, 2018) [16]. Five states in India *viz.*, Gujarat (37.7%), Andhra Pradesh (17%), Rajasthan (14.1%), Karnataka (9.8%) and Maharashtra (5%) account for about 83.7% of the total groundnut area of the country (Agricultural and Processed Food Products Export Development, 2018) [2].
In Andhra Pradesh, groundnut is grown in an area of 735 million hectares with a total production of 1048.41 million tonnes and productivity of 1426 kg ha^{-1} (Ministry of Agriculture, 2018) [16]. In Chittoor district, groundnut is grown in an area of 1.29 lakh hectares, with a total production of 10.5 lakh tonnes and productivity of 1442 kg ha^{-1} (Directorate of Economics and Statistics, 2018) [9]. Groundnut crop is attacked by about 100 species of insect pests which contribute to the total yield loss up to 40.2% as observed by Baskaran and Rajavel (2013) [3]. A total of 13 species of sucking insect pests were found feeding and damaging groundnut crop (Kandakoor *et al*., 2012) [12]. The major sucking insect pest complex of groundnut includes thrips, *Scirtothrips dorsalis* Hood, *Frankliniella schultzei* Trybom, *Thrips palmi* Karny, *Caliothrips indicus* Bagnall; leafhopper, *Empoasca kerri* Pruthi; aphid, *Aphis gossypii* Glover and few minor sucking pests. Amongst, leafhoppers and thrips are of major importance on groundnut crop (David and Ramamurthy, 2011) [8] causing a serious damage throughout the crop growth period and losses may extend up to 22 per cent and 40 per cent, respectively (Ghewande, 1987) [11].
Sucking insect pest complex of groundnut besides causing yield loss through direct feeding activity, also act as vectors of important viral diseases that cause eventual disease and death of plants. Thrips act as vectors for bud necrosis/stem necrosis disease caused by tomato spotted wilt virus and the disease has affected 2.25 lakh hectares in Anantapur district during *Kharif*, 2000 causing a monitory loss of 3 billion rupees (Rao *et al.*, 2003) [18]. Aphids (*Aphis craccivora*) are polyphagous and transmit groundnut rosette virus, peanut mottle virus and peanut stripe virus which cause yield loss up to 40% (Khan and Hussain, 1965) [13]. Many insecticides have been successfully tried against sucking insect pests of groundnut. Application of newer molecules has an excellent opportunity in the management of various

pests as they are pest-specific, eco-friendly and less persistent but the information on their efficacy of against major sucking insect pests of groundnut is limited. Hence, the present experiment has been conducted to assess the performance and to compare the efficacy of newer molecules of insecticides against leafhoppers (*Empoasca kerri*), aphids (*Aphis craccivora*) and thrips (*Scirtothrips dorsalis*) on Groundnut

Material and Methods

A field trial was conducted during *kharif*, 2019 at the dryland farm, S. V. Agricultural College, Tirupati with groundnut variety Dharani sown in in a randomized block design to evaluate the efficacy of nine insecticides *viz.*, thiamethoxam @ 0.4 g l^{-1}, thiacloprid @ 0.25 ml l^{-1}, flonicamid @ 0.4 g l^{-1}, pymetrozine @ 0.6 g l^{-1}, dinotefuran @ 0.3 g l^{-1}, spinosad @ 0.3 ml l^{-1}, imidacloprid @ 0.3 ml l^{-1}, acetamiprid+fipronil @ 2.0 ml l^{-1} and fipronil @ 2 ml l^{-1} against sucking insect pest complex *viz.,* leafhoppers, aphids and thrips in groundnut crop. Treatments were given twice during the crop period. Pre-treatment observations on pest population were taken on top 3 leaves one day before the application of the treatements. Pest population was recorded by observing ten randomly selected plants from each treatment at one day prior to insecticide application and one, five, ten and fifteen days after each spraying. Per cent reduction of sucking insect pest population in treatments over control plots was estimated by using the formula given by Abbott (1925) [1].

$$\text{Population reduction over control (\%)} = \frac{\text{Population in untreated check} - \text{Population in treatment}}{\text{Population in untreated check}} \text{X100}$$

In order to find out the efficacy of various insecticides used in the experiment, the statistical constants *i.e.,* mean, standard error of mean, critical difference, and co-efficient of variation for each quantitative characters were computed by the method of analysis of variance (ANOVA) used for randomized block design.

Results and Discussion

Efficacy of insecticides against leafhoppers, *Empoasca kerri*

Though there was a uniform distribution of leafhoppers a day before insecticidal application, significant differences in the efficacies of insecticides was noticed at 1, 5, 10 and 15 days after both the insecticidal sprays. A perusal of results on cumulative efficacy of two sprays against leafhopper, *Empoasca kerri* revealed that all the treatments were superior to control in reducing the leafhopper population at 1, 5, 10 and 15 days after treatment (table 1). At 1 DAT (Days After Treatment) highest percent reduction of leafhopper population was observed in acetamiprid+fipronil @ 2 ml l^{-1} (91.14%) followed by imidacloprid @ 0.3 ml l^{-1} (89.38%), however both the treatments were on par with each other. The other treatments in the descending order of efficacy (per cent population reduction over control) were pymetrozine @ 0.6 g l^{-1} (84.88%), thiamethoxam @ 0.4 g l^{-1} (84.14%), flonicamid @ 0.4 g l^{-1} (76.78%), dinotefuron @ 0.3 g l^{-1} (76.09%), thiacloprid @ 0.4 g l^{-1} (72.79%), fipronil @ 2 ml l^{-1} (74.25%) and spinosad @ 0.3 ml l^{-1} (62.57%). At 5 DAT also same trend was observed and treatments *viz.,* acetamiprid+fipronil @ 2 ml l^{-1} (81.97%), imidacloprid @ 0.3 ml l^{-1} (80.97%), and pymetrozine @ 0.6 g l^{-1} (76.69%) were found superior to rest of the treatments and were on par with each other. The other treatments in the descending order of efficacy (per cent population reduction over control) were thiamethoxam @ 0.4 g l^{-1} (75.82%), flonicamid @ 0.4 g l^{-1} (72.69%), dinotefuron @ 0.3 g l^{-1} (71.57%), fipronil @ 2 ml l^{-1} (70.53%), thiacloprid @ 0.4 g l^{-1} (65.08%) and spinosad @ 0.3 ml l^{-1} (60.68%). At 10 and 15 DAT also treatments acetamiprid+fipronil @ 2 ml l^{-1} (67.39% & 58.46% reduction of leafhopper population, respectively), imidacloprid @ 0.3 ml l^{-1} (66.79% and 56.52%) were found superior to rest of the treatments and were found on par with each other. The other treatments in the descending order of efficacy were pymetrozine @ 0.6 g l^{-1} (59.98% & 47.84%), thiamethoxam @ 0.4 g l^{-1} (59.38% & 47.11%), flonicamid @ 0.4 g l^{-1} (55.68% & 43.84%), dinotefuron @ 0.3 g l^{-1} (55.08% & 41.77%), fipronil @ 2 ml l^{-1} (54.24% & 40.54%) thiacloprid @ 0.4 g l^{-1} (51.72% & 37.93%) and spinosad @ 0.3 ml l^{-1} (44.81% & 33.93%).

The overall mean efficacy of four observations recorded at one, five, ten and fifteen days after two sprays indicated that the plots treated with acetamiprid+fipronil @ 2 ml l^{-1}and imidacloprid @ 0.3 ml l^{-1}recorded highest reduction of leafhopper population and remained significantly superior over all the other treatments with 73.58 and 72.32 per cent reduction over control, respectively and both the treatments were at par with each other. The next best treatments in the descending order of efficacy were pymetrozine @ 0.6 g l^{-1}and thiamethoxam @ 0.4 g l^{-1}with 66.20 and 65.41 per cent reduction over control, respectively and both the treatments were at par with each other. The next treatments in the descending order of efficacy were flonicamid @ 0.4 g l^{-1}(61.32%), dinotefuron @ 0.3 g l^{-1}(60.13%) and fipronil @ 2 ml l^{-1}(58.96%) and all the three treatments were at par with each other. The next effective treatment was thiacloprid @ 0.4 g l^{-1}with 55.44 per cent reduction over control and was statistically at par with fipronil @ 2 ml l^{-1}. Spinosad @ 0.3 ml l^{-1}with 49.74 per cent reduction over control was least effective in reducing leafhopper population compared to above treatments (Table 1) (Fig 1).

Table 1: Overall efficacy of treatments against leafhoppers, Empoasca KERRI

S. No.	Treatment	Dose	PTC	Per cent reduction of leafhopper population								Mean% reduction
				1 DAT		5 DAT		10 DAT		15 DAT		
				Mean	% reduction	Mean	% reduction	Mean	% reduction	Mean	% reduction	
T_1	Thiamethoxam 70% WS	0.4 g l^{-1}	13.20	1.75	84.14^{b} (66.72)	2.93	75.82^{bcd} (60.77)	5.33	59.38^{b} (50.43)	7.30	47.11^{b} (43.34)	65.41^{b} (54.02)
T_2	Thiacloprid 240% SC	0.25 ml l^{-1}	12.98	2.78	72.79^{c} (58.88)	4.17	65.08^{ef} (54.12)	6.20	51.72^{c} (46.08)	8.57	37.93^{de} (38.02)	55.44^{d} (48.20)
T_3	Flonicamid 50% WG	0.4 g l^{-1}	13.18	2.43	76.78^{c} (61.41)	3.30	72.69^{cd} (58.55)	5.78	55.68^{bc} (48.30)	7.75	43.84^{bc} (41.46)	61.32^{c} (51.57)
T_4	Pymetrozine 50% WDG	0.6 g l^{-1}	13.62	1.68	84.88$_{ab}$ (67.25)	2.82	76.69^{abc} (61.36)	5.25	59.98^{b} (50.78)	7.20	47.84^{b} (43.76)	66.20^{b} (54.51)
T_5	Dinotefuron 50% WP	0.3 g l^{-1}	13.58	2.50	76.09^{c} (60.85)	3.45	71.57^{cd} (57.92)	5.88	55.08^{bc} (47.95)	8.03	41.77^{cd} (40.26)	60.13^{c} (50.89)
T_6	Spinosad 45% SC	0.3 ml l^{-1}	13.52	3.90	62.57^{d} (52.40)	4.73	60.68^{f} (51.20)	7.20	44.81^{d} (42.03)	9.12	33.93^{e} (35.61)	49.74^{e} (44.88)
T_7	Imidacloprid 17.8% SL	0.3 ml l^{-1}	13.40	1.17	89.38^{ab} (71.14)	2.30	80.97^{ab} (64.23)	4.38	66.79^{a} (54.85)	6.00	56.52^{a}(48.78)	72.32^{a} (58.30)
T_8	Acetamiprid + Fipronil 4% SC	2 ml l^{-1}	13.78	1.03	91.14^{a} (73.17)	2.18	81.97^{a} (65.02)	4.28	67.39^{a} (55.21)	5.73	58.46^{a} (49.92)	73.58^{a} (59.13)
T_9	Fipronil 5% SC	2ml l^{-1}	13.60	2.68	74.25^{c} (59.74)	3.57	70.53^{de} (57.21)	6.03	54.24^{c} (47.46)	8.21	40.54^{cd} (39.51)	58.96^{cd} (50.19)
T_{10}	Control	-	13.60	10.74	-	12.08	-	13.15	-	13.80	-	-
SEm±					2.44		2.42		2.02		1.67	1.64

CD (5%)				5.98		5.92		4.95		4.07	4.02
CV (%)				7.41		7.90		7.91		7.58	6.04

*Figures in parenthesis are angular transformed values; PTC: Pre treatment count

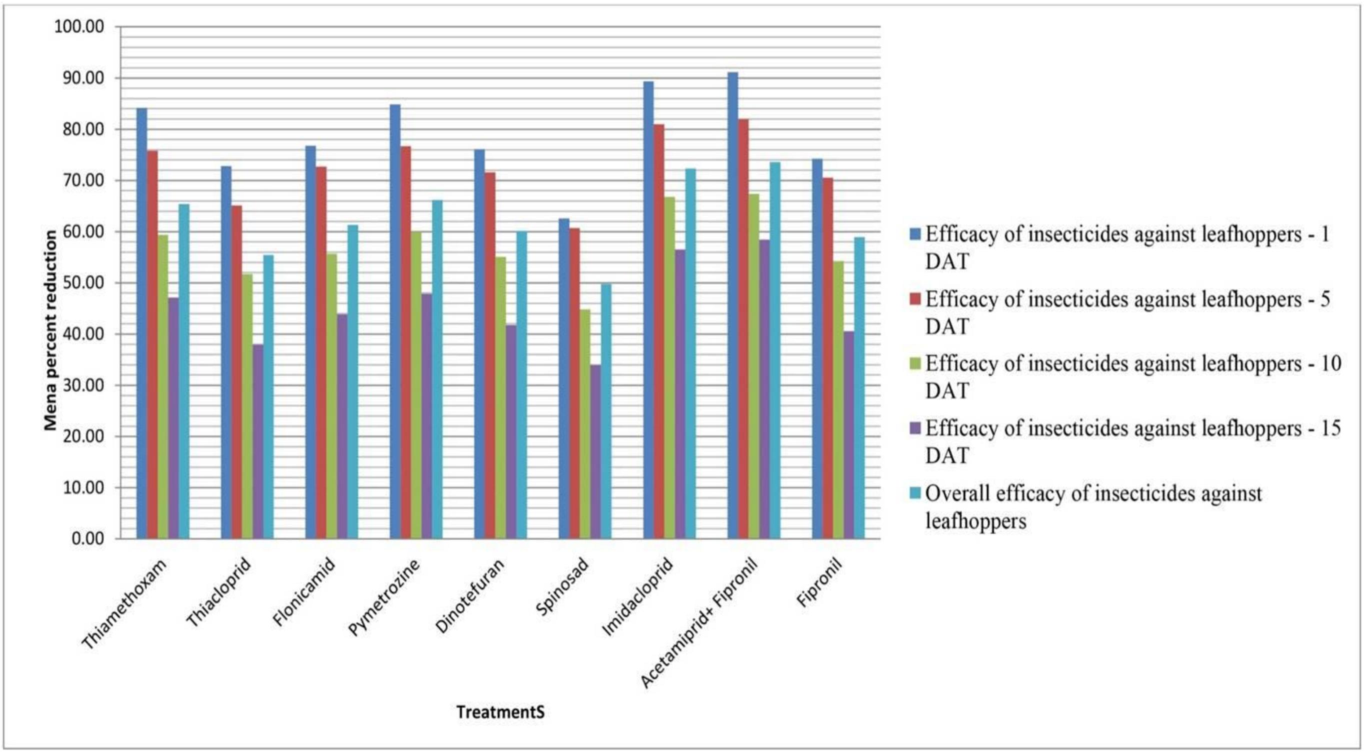

Fig 1: Overall efficacy of treatments against leafhoppers, *Empoasca kerri*

Efficacy of insecticides against aphids, *Aphis craccivora*

The observations on pre-treatment count of aphids in the table 2 revealed that there was no significant variation among their populations in the experimental plots indicating a homogeneous distribution of the pest. However, significant difference in the number of aphids was observed after the implementation of treatments.

A perusal of results on cumulative efficacy of two sprays against aphids, *Aphis cracivora*, revealed that all the treatments were superior to control in reducing the aphid population at 1, 5, 10 and 15 days after treatment (table 2). At 1 DAT (Days After Treatment) highest percent reduction of aphid population was observed in acetamiprid+fipronil @ 2 ml l^{-1} (91.51%) followed by imidacloprid @ 0.3 ml l^{-1} (90.32%), however both the treatments were on par with each other. The other treatments in the descending order of efficacy (per cent population reduction over control) were pymetrozine @ 0.6 g l^{-1} (85.38%), thiamethoxam @ 0.4 g l^{-1} (84.47%), flonicamid @ 0.4 g l^{-1} (78.34%), dinotefuron @ 0.3 g l^{-1} (77.10%), fipronil @ 2 ml l^{-1} (75.37%), thiacloprid @ 0.4 g l^{-1} (72.09%) and spinosad @ 0.3 ml l^{-1} (63.89%). At 5 DAT also same trend was observed and treatments *viz.*, acetamiprid+fipronil @ 2 ml l^{-1} (82.91%) and imidacloprid @ 0.3 ml l^{-1} (82.13%) were found superior to rest of the treatments and were on par with each other. The other treatments in the descending order of efficacy (per cent population reduction over control) were pymetrozine @ 0.6 g l^{-1} (76.69%) thiamethoxam @ 0.4 g l^{-1} (75.05%), flonicamid @ 0.4 g l^{-1} (71.86%), dinotefuron @ 0.3 g l^{-1} (69.80%), fipronil @ 2 ml l^{-1} (68.93%), thiacloprid @ 0.4 g l^{-1} (66.77%) and spinosad @ 0.3 ml l^{-1} (54.26%). At 10 and 15 DAT also treatments acetamiprid+fipronil @ 2 ml l^{-1} (63.32% & 57.92% reduction of leafhopper population, respectively), imidacloprid @ 0.3 ml l^{-1} (62.08% and 56.81%) were found superior to rest of the treatments and were found on par with each other. The other treatments in the descending order of efficacy were pymetrozine @ 0.6 g l^{-1} (55.88% & 51.46%), thiamethoxam @ 0.4 g l^{-1} (54.28% & 49.37%), flonicamid @ 0.4 g l^{-1} (51.60% & 44.07%), dinotefuron @ 0.3 g l^{-1} (50.17% & 42.83%), fipronil @ 2 ml l^{-1} (48.41% & 41.14%) thiacloprid @ 0.4 g l^{-1} (44.86% & 39.23%) and spinosad @ 0.3 ml l^{-1} (39.27% & 31.94%).

The overall mean efficacy of four observations recorded at one, five, ten and fifteen days after two sprays indicated that the plots treated with acetamiprid+fipronil @ 2 ml $l^{-1}$and imidacloprid @ 0.3 ml l^{-1}recorded highest per cent reduction of aphid population and remained significantly superior over all the other treatments with 73.58 and 72.56 per cent reduction over control, respectively and both the treatments were at par with each other. The next effective treatments in the descending order of efficacy were pymetrozine @ 0.6 g $l^{-1}$and thiamethoxam @ 0.4 g $l^{-1}$with 67.06 and 65.45 per cent reduction over control, respectively and both the treatments were at par with each other. The next treatments in the descending order of efficacy were flonicamid @ 0.4 g l^{-1}, dinotefuron @ 0.3 g $l^{-1}$and fipronil @ 2 ml $l^{-1}$with 61.15, 59.66 and 58.13 per cent reduction over control, respectively and all the three treatments were at par with each other. The next effective treatment was thiacloprid @ 0.4 g $l^{-1}$with 55.68 per cent reduction over control and was at par with fipronil @ 2 ml l^{-1}. Spinosad @ 0.3 ml $l^{-1}$with 47.32 per cent reduction over control was least effective compared to above treatments (Table 2) (Fig 2).

Table 2: Overall efficacy of treatments against aphids, *Aphis craccivora*

S. No.	Treatment	Dose	PTC	Per cent reduction of aphid population								Mean% reduction
				1 DAT		5 DAT		10 DAT		15 DAT		
				Mean	% reduction	Mean	% reduction	Mean	% reduction	Mean	% reduction	
T_1	Thiamethoxam 70% WS	0.4 g l^{-1}	17.63	2.87	84.47^{bc} (66.93)	4.37	75.05^{bc} (60.10)	8.28	54.28^{bc} (47.48)	10.13	49.37^{b} (44.66)	65.45^{b} (54.03)
T_2	Thiacloprid 240% SC	0.25 ml l^{-1}	17.77	4.77	72.09^{d} (59.22)	5.85	66.77^{c} (54.86)	9.88	44.86^{e} (42.03)	12.17	39.23^{d} (38.74)	55.68^{d} (48.35)
T_3	Flonicamid 50% WG	0.4 g l^{-1}	17.52	3.93	78.34^{cd} (62.33)	4.93	71.86^{bc} (58.02)	8.80	51.60^{bcd} (45.95)	11.20	44.07^{c} (41.61)	61.15^{c} (51.47)
T_4	Pymetrozine 50% WDG	0.6 g l^{-1}	18.18	2.73	85.38^{ab} (67.59)	4.05	76.69^{b} (61.32)	7.98	55.88^{b} (48.41)	9.73	51.46^{b} (45.86)	67.06^{b} (55.01)
T_5	Dinotefuron 50% WP	0.3 g l^{-1}	18.15	4.25	77.10^{d} (61.45)	5.27	69.80^{c} (56.78)	9.02	50.17^{cd} (45.12)	11.48	42.83^{cd} (40.88)	59.66^{c} (50.61)
T_6	Spinosad 45% SC	0.3 ml l^{-1}	18.85	6.67	63.89^{e} (53.10)	7.88	54.26^{d} (47.48)	11.05	39.27^{f} (38.81)	13.65	31.94^{e} (34.37)	47.32^{e} (43.47)
T_7	Imidacloprid 17.8% SL	0.3 ml l^{-1}	18.32	1.77	90.32^{ab} (71.94)	3.12	82.13a (65.11)	6.87	62.08^{a} (52.02)	8.65	56.81^{a} (48.95)	72.56^{a} (58.45)
T_8	Acetamiprid + Fipronil 4% SC	2 ml l^{-1}	18.30	1.57	91.51^{a} (73.11)	2.98	82.91^{a} (65.69)	6.63	63.32^{a} (52.76)	8.45	57.92^{a} (49.59)	73.58^{a} (59.10)
T_9	Fipronil 5% SC	2ml l^{-1}	17.83	4.57	75.37^{d} (60.29)	5.43	68.93^{c} (56.20)	9.37	48.41^{de} (44.11)	11.78	41.14^{cd} (39.90)	58.13^{cd} (49.71)
T_{10}	Control	-	21.10	18.40	-	17.62	-	18.15	-	20.05	-	-
SEm±					2.63		221		2.12		1.58	1.67
CD (5%)					6.44		5.40		5.19		3.87	4.10
CV (%)					7.91		7.27		8.81		7.12	6.17

*Figures in parenthesis are angular transformed values; PTC: Pre treatment count

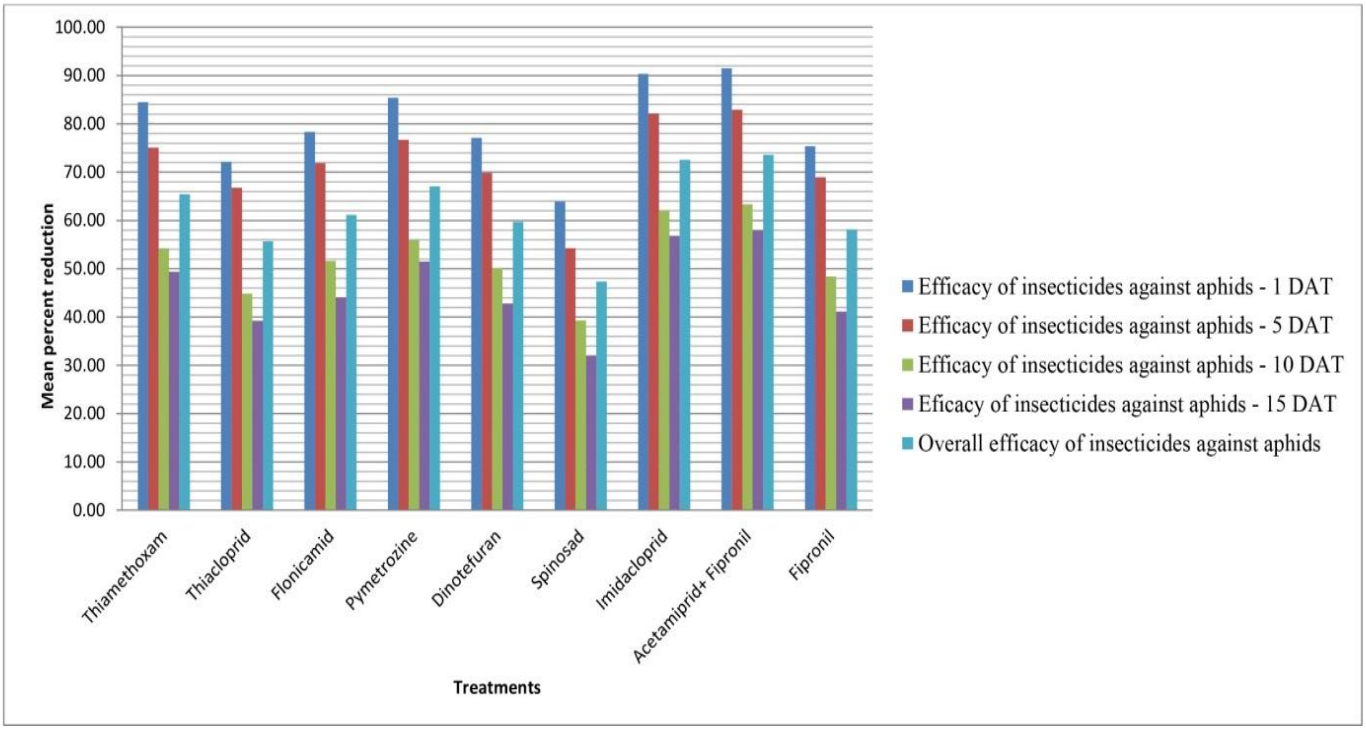

Fig 2: Overall efficacy of treatments against aphids, *Aphis craccivora*

Efficacy of insecticides against thrips, *Scirtothrips dorsalis*

The variance in the number of thrips among all the experimental plots before the insecticidal treatments was non-significant. However, all the treatments have significantly brought down the thrips population when compared to control. A perusal of results on cumulative efficacy of two sprays against thrips, *Scirtothrips dorsalis*, revealed that all the treatments were superior to control in reducing the thrips population at 1, 5, 10 and 15 days after treatment. At 1 DAT (Days After Treatment) highest percent reduction of thrip population was observed in acetamiprid+fipronil @ 2 ml l^{-1} (89.91%) followed by fipronil @ 2 ml l^{-1} (88.49%) and spinosad @ 0.3 ml l^{-1} (82.72%) however all the three treatments were on par with each other. The other treatments in the descending order of efficacy (per cent population reduction over control) were imidacloprid @ 0.3 ml l^{-1} (85.13%), pymetrozine @ 0.6 g l^{-1} (78.21%), thiamethoxam @ 0.4 g l^{-1} (77.43%), flonicamid @ 0.4 g l^{-1} (74.20%), dinotefuron @ 0.3 g l^{-1} (71.88%) and thiacloprid @ 0.4 g l^{-1} (67.43). At 5 DAT also same trend was observed and treatments *viz.*, acetamiprid+fipronil @ 2 ml l^{-1} (82.11%), fipronil @ 2 ml l^{-1} (81.08%), imidacloprid @ 0.3 ml l^{-1} (79.51%) and spinosad @ 0.3 ml l^{-1} (74.74%) were found superior to rest of the treatments and were on par with each other. The other treatments in the descending order of efficacy (per cent population reduction over control) were pymetrozine @ 0.6 g l^{-1} (69.15%) thiamethoxam @ 0.4 g l^{-1} (66.74%), flonicamid @ 0.4 g l^{-1} (63.85%), dinotefuron @ 0.3 g l^{-1} (61.01%) and thiacloprid @ 0.4 g l^{-1} (57.38%). At 10 and 15 DAT also treatments acetamiprid+fipronil @ 2 ml l^{-1} (66.11% & 60.32% reduction of thrip population, respectively) and fipronil @ 2 ml l^{-1} (64.74% & 58.53%), were found superior to rest of the treatments and were found on par with each other. The other treatments in the descending order of efficacy were imidacloprid @ 0.3 ml l^{-1} (61.10% and 57.17%), spinosad @ 0.3 ml l^{-1} (57.04% & 53.48%). pymetrozine @ 0.6 g l^{-1} (52.82% & 47.87%), thiamethoxam @ 0.4 g l^{-1} (50.92% & 46.69%), flonicamid @ 0.4 g l^{-1} (49.67% & 42.22%), dinotefuron @ 0.3 g l^{-1} (48.81% & 40.45%), and thiacloprid @ 0.4 g l^{-1} (40.40% & 36.69%).

The overall mean efficacy of four observations recorded at one, five, ten and fifteen days after two sprays indicated that the plots treatedwith acetamiprid+fipronil @ 2 ml l^{-1}, fipronil @ 2 ml $l^{-1}$and imidacloprid @ 0.3 ml l^{-1} showed highest reduction of thrips population with 74.52, 73.19 and 70.67 per cent reduction over control, respectively and all the three treatments were at par with each other. The next effective treatment was spinosad @ 0.3 ml $l^{-1}$with 66.68 per cent reduction over control and was at par with imidacloprid @ 0.3 ml l^{-1}. The next treatments in the descending order of efficacy were pymetrozine @ 0.6 g l^{-1} (61.37%), thiamethoxam @ 0.4 g l^{-1}(59.96%) and flonicamid @ 0.4 g l^{-1} (57.08%) and all the three treatments were at par with each other. The next effective treatment was dinotefuron @ 0.3 g l^{-1} with 54.77 per cent reduction over control and was statistically at par with flonicamid @ 0.4 g l^{-1}. Thiacloprid @ 0.4 g l^{-1}recorded least per cent reduction over control (48.37%) (Table 3) (Fig 3).

Acetamiprid+fipronil @ 2 ml l^{-1} recorded highest per cent reduction of sucking insects *viz*., leafhoppers, aphids and thrips than applying them as individual treatments. This treatment is further followed by sole neo-nicotinoids, fipronil and pymetrozine. Acetamiprid+fipronil@ 2 ml l^{-1} recorded highest per cent reduction of sucking insects *viz*., leafhoppers, aphids and thrips due to it's combination effect which affects both the central nervous system and peripheral nervous system of insects resulting in immediate death of insects. Acetamiprid+fipronil has ovicidal, adulticidal and nymphicidal action and is very effective against sucking pests. Similar results were reported by Kandakoor (2012) [12] who disclosed that acetamiprid 20 SP @ 100 ml ha^{-1} was effective in reducing of thrips population in groundnut with a mean per cent reduction of 79.27 per cent. These results are in close concordance with those of Roshan *et al*. (2018) [19] who found that acetamiprid+fipronil 60 WDG @ 35 g a.i ha^{-1} was most effective followed by imidacloprid 17.8 SL @25 g a.i ha^{-1} in controlling sucking insect pest complex *viz*., leafhoppers, aphids and thrips. Results of the current experiment are also parallel to those of Swathi *et al.* (2018) [23] who recorded the efficacy of this combination insecticide @ 2 ml l^{-1} against thrips which recorded with 70.81 per cent reduction over untreated control. There are plethora of evidences regarding the efficacy of neonicotinoids and fipronil as sole treatments against sucking pests in groundnut and other crops. Fipronil 5 SC @ 0.01 per cent was effective in reducing thrips population in chilli with mean per cent reduction of 76.38 per cent over control (Samota *et al*., 2017) [20]. Kumar and Kumar (2018) [14] observed that significantly low population of thrips was recorded (4.0 thrips/terminal bud) in the treatment of fipronil 80% WG and it was at par with fipronil 5% SC (4.0 thrips/terminal bud) and both the treatments were found superior in management of thrips in groundnut, which further confirms the results obtained during present study. Seetharamu *et al.* (2020) [21] observed that acetamiprid 20 SL @ 0.125 g l^{-1} proved to be highly effective against *A. craccivora* in grain legumes with mortality percentage of 98.33, which is in conformity with the present findings. Yasa *et al*. (2010) [26] also observed highest per cent reduction of leafhoppers and thrips population in the treatment of imidacloprid @ 26.7 g a.i. ha^{-1} followed by acetamiprid @ 12.5 g a.i. ha^{-1} and thiamethoxam @ 15.5 g a.i. ha^{-1}. Biswas (2015) [5] noticed that imidacloprid (Admire 200 SL @ 0.50 ml l^{-1}) recorded highest population reduction of leafhoppers (80.25%) over the control in groundnut, which supports present findings.

The superiority of the combination insecticide (acetamiprid + fipronil) in the current study may be due to various factors of sole insecticides namely neonicotinoids and fipronil that are present in the formulation. The variations in the efficacy of neo-nicotinoids can be attributed to the multiple receptor targets in various insect species *i.e*., imidacloprid acts on nAChR1 and not on nAChR2; nicotine, acetamiprid, and clothianidin act as agonists of nAChR2 (Bordereau-Dubois *et al*., 2012 [6]; Calas-List *et al*., 2013 [7]); thiamethoxam is able to bind to mixed nicotinic/muscarinic receptors (Lapied *et al*. 1990) [15] and can act on imidacloprid-sensitive nAChR1 and imidacloprid-insensitive nAChR2 subtypes (Thany 2009 [24], 2011 [25]). Efficacy of certain neo-nicotinoids can be further enhanced by the appearance of their metabolite like clothianidin in case of thiamethoxam (Benzidane *et al*. 2010) [4]. Besides, neonicotinoids are also reported to stimulate the growth of crop under stress conditions by inducing plant defense mechanisms and thus increasing the yield. On the other, fipronil is also known to act on more than one target site *viz*., γ-aminobutyric acid receptor to block the chloride channel and also block glutamate-activated chloride channels. It is effective against species of insects that have become resistant to most insecticides, including those acting on the γ-aminobutyric acid receptor. Fipronil block of the glutamate-activated chloride channel is deemed responsible, at least partially, for the higher selective toxicity to insects over mammals and for the lack of cross-resistance (Narahashi *et al*., 2007) [17]. It is reported that very subtle differences in subunit sequence can lead to nAChRs resistant to neonicotinoids or to nAChRs on which neonicotinoids can act agonistically or antagonistically (Simon *et al*., 2014) [22] and combining neo-nicotinoids with phenyl pyrazoles might counter act this development of resistance. All these reasons might have contributed to the success of combination of acetamiprid and fipronil. Apart from this, acetamiprid+fipronil has ovicidal, adulticidal and nymphicidal action and is very effective against sucking pests.

Table 3: Overall cumulative efficacy of treatments against thrips, *Scirtothrips dorsalis*

S. No.	Treatment	Dose	PTC	Per cent reduction of thrip population								Mean% reduction
				1 DAT		5 DAT		10 DAT		15 DAT		
				Mean	% reduction	Mean	% reduction	Mean	% reduction	Mean	% reduction	
T_1	Thiamethoxam 70% WS	0.4 g l^{-1}	13.12	2.90	77.43^{bc} (61.81)	4.43	66.74^{cd} (54.98)	6.57	50.92^{de} (45.54)	7.87	46.69^{d} (43.06)	59.96^{c} (50.83)
T_2	Thiacloprid 240% SC	0.25 ml l^{-1}	13.15	3.95	67.43^{d} (55.76)	5.73	57.38^{e} (49.38)	7.43	44.40^{f} (41.61)	9.37	36.69^{e} (37.17)	48.37^{e} (44.08)
T_3	Flonicamid 50% WG	0.4 g l^{-1}	13.13	3.28	74.20^{cd} (59.54)	4.82	63.85^{cde} (53.28)	6.73	49.67^{de} (44.82)	8.53	42.22^{de} (40.47)	57.08^{cd} (49.13)
T_4	Pymetrozine 50% WDG	0.6 g l^{-1}	12.82	2.80	78.21^{bc} (62.42)	4.12	69.15^{bc} (56.44)	6.32	52.82^{d} (46.65)	7.70	47.87^{cd} (43.77)	61.37^{c} (51.65)
T_5	Dinotefuron 50% WP	0.3 g l^{-1}	13.13	3.65	71.88^{cd} (58.35)	5.20	61.01^{de} (51.52)	6.85	48.81^{e} (44.32)	8.80	40.45^{e} (39.42)	54.77^{d} (47.78)
T_6	Spinosad 45% SC	0.3 ml l^{-1}	13.43	2.20	82.72^{ab} (65.51)	3.37	74.74^{ab} (60.11)	5.75	57.04^{c} (49.09)	6.87	53.48^{bc} (47.04)	66.68^{b} (54.85)
T_7	Imidacloprid 17.8% SL	0.3 ml l^{-1}	13.62	1.88	$85.13a^{b}$ (67.36)	2.72	79.59^{a} (63.52)	5.20	61.10^{b} (51.53)	6.32	57.17^{ab} (49.21)	70.67^{ab} (57.37)
T_8	Acetamiprid + Fipronil 4% SC	2 ml l^{-1}	13.18	1.28	89.91^{a} (71.55)	2.38	82.11^{a} (65.24)	4.53	66.11^{a} (54.48)	5.85	60.32^{a} (51.11)	74.52^{a} (59.84)
T_9	Fipronil 5% SC	2ml l^{-1}	12.75	1.47	88.49^{a} (70.25)	2.52	81.08^{a} (64.67)	4.72	64.74^{ab} (53.65)	6.12	58.53^{ab} (50.02)	73.19^{a} (58.99)
T_{10}	Control	-	13.59	12.62	-	13.38	-	13.40	-	14.80	-	-
SEm±					2.98		2.91		1.53		2.32	1.76

CD (5%)				7.29		7.12		3.74		5.68	4.31
CV (%)				9.01		9.70		6.14		10.02	6.42

*Figures in parenthesis are angular transformed values; PTC: Pre treatment count

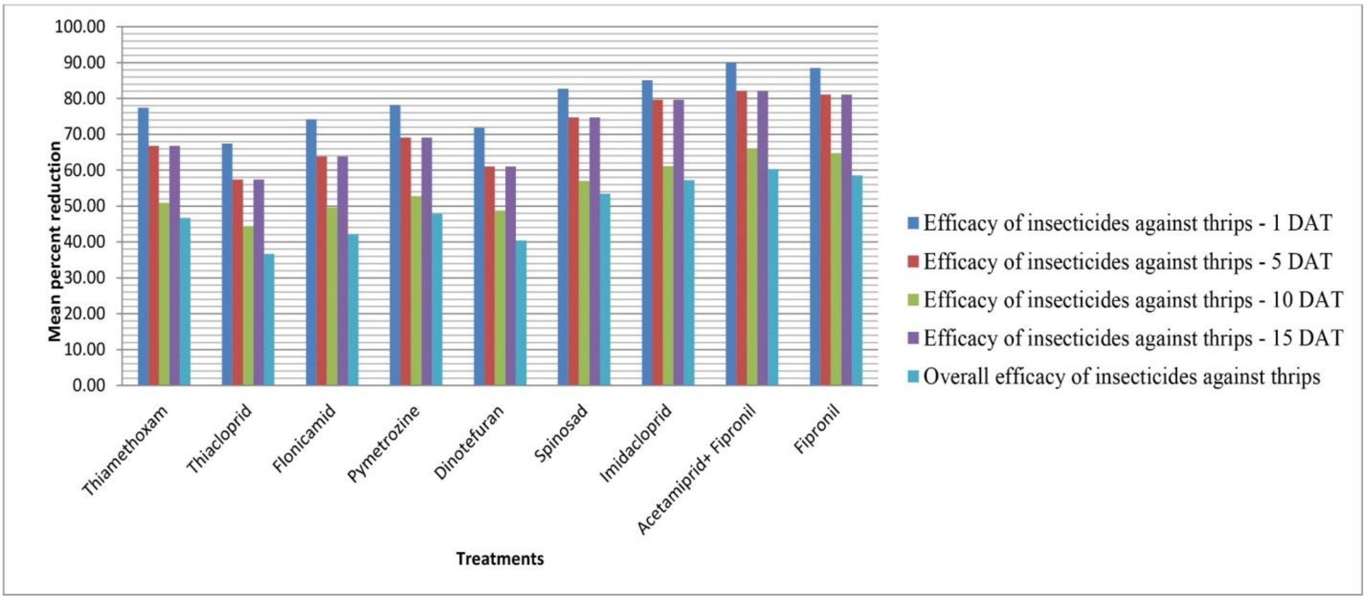

Fig 3: Overall cumulative efficacy of treatments against thrips, *Scirtothrips dorsalis*

Conclusion

Due to multiple target sites, production of synergistic metabolites, stimulation of plant self-defense mechanisms, high selective toxicity towards insects and lack of cross resistance, combination of neo-nicotinoids and phenyl pyrazoles may effectively be included in the Integrated Pest Management and resistance management strategies of groundnut pest complex.

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