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RESEARCH ARTICLE

Bioefficacy of F9252 (Bifenthrin 8% + Clothianidin 10% SC) against Insect Pests of Groundnut

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ABSTRACT

Two field experiments were conducted to assess the efficacy of the F9252 (bifenthrin 8% + clothianidin 10% SC) a synthetic pyrethroids and neonicotinoid combination ready mix formulation against white grub and sucking pests of groundnut at Tamil Nadu Agricultural University, Coimbatore during February to May 2016 and May - July 2017 using Groundnut variety TMV 7 in randomized block design (RBD). Applications of insecticides were made at the time of planting and at 30 days after sowing. Assessment of the phytotoxic effect of F9252 at X, 2X and 4X doses on groundnut crop was also evaluated. The results revealed that, the per cent plant mortality due to white grub infestation is less than 1 per cent at the plots treated with F9252 @ 100 + 125 g a.i. ha^{-1} and F9252 @ 80 + 100 g a.i. ha^{-1} at the time of harvest and it was 14.73 per cent in untreated control. The data on per cent control of sucking pests (aphids and thrips) indicated that highest per cent control was recorded in the treatments, F9252 at 100+125 g a.i. ha^{-1} and F9252 at 80+100 g a.i. ha^{-1} and these two treatments were comparatively superior to all other treatments. Based on per cent reduction of pest populations over untreated control the order of relative efficacy of the test insecticides in controlling the sucking pests were, F9252 @ 100 + 125 g a.i. ha^{-1} = F9252 @ 80 + 100 g a.i. ha^{-1} > F9252 @ 60 + 75 g a.i. ha^{-1} = clothianidin @ 125 g a.i. ha^{-1} = clothianidin @ 100 g a.i. ha^{-1} > phorate 10 G @ 2500 g a.i. ha^{-1} = chlorpyrifos 20 EC @ 225g a.i. ha^{-1} = bifenthrin @ 80 g a.i. ha^{-1}. F9252 at 80 + 100, 160 + 200 and 240 + 300 g a.i. ha^{-1} did not cause any visual phytotoxic symptoms in both the season of experimentation. The groundnut pod yield was maximum in the F9252 @ 100 + 125 g a.i. ha^{-1} (83.10 % increase over untreated control) and which was statistically on par with the yield of F9252 @ 80 + 100 g a.i. ha^{-1} (80.19 % increase over untreated control). Hence, F9252 @ 80 + 100 g a.i. ha^{-1} is recommended to get maximum yield with effective control of groundnut pests in the comparatively low dose of insecticide exposure to the environment.

Keywords: *Groundnut; White grub; Sucking pests; Clothianidin; Bifenthrin.*

INTRODUCTION

Groundnut or peanut (*Arachis hypogaea* L.) is a cultivated annual oilseed crop grown in many tropical and sub tropical countries for its seeds, which contain upto 48 per cent of nondrying oil and about 26 per cent protein. It is also known as peanut, earthnut, monkey nut, and goobers (Beghin *et al.,* 2003). India is the second largest producer of the groundnut next to China and nearly 16 per cent of groundnut production is contributed by India to the world production. In India, groundnut is cultivated about 4.56 million hectares, with the total production of 6.77 million tonnes and with the average yield of 1486 kg/hectare during 2016-17 (Gayathri, 2018).Groundnut is grown throughout the year in India and Gujarat, Rajasthan and Tamil Nadu are the major producing states. The mean productivity of groundnut in India is very low with 1750 kg/ha, when compared to mean global productivity of 2149 kg/ha (Indiragandhi *et al.,* 2018), this is due to various constraints enforced by biotic, abiotic and socioeconomic factors. Insect pests represent a major yield constraint in groundnut by direct damage or as vectors of virus diseases. Over one hundred insect species recorded to be the potential pests on groundnut in India (Amin, 1988; Nandagopal, 1992) only few species such as

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whitegrubs, aphid and thrips are causing extensive damage and drastic yield reduction in all groundnut growing areas.

Among various pest management strategies enforced to control the pests of groundnut, farmers use insecticide as a first line of defence mechanism against the pests of groundnut. In spite of, various ill effects like development of resistance, resurgence and residues in the harvested produces caused by insecticide, till date there is no alternate and effective strategies like insecticide is explored in the management of groundnut pests in the field. Hence there is a need to develop safe and effective insecticide molecules to overcome environmental and ecological issues. Bifenthrin is a third generation photostable synthetic pyrethroid having applications both in agriculture and in public health control. Bifenthrin is effective for control of insect pests of cotton (Ali and Karim, 1994; Balakrishnan *et al.,* 2009), rice (Veeravel and Ravivarman, 2010), vegetables (Gupta *et al.,* 2009) and fruits (Reddy and Rao, 2002). It also shows good bioefficacy against insect pests of brinjal (Sudhakar *et al.*, 1998; Jethva *et al.,* 2016), tomato (Rushtapakornchai and Petchwichit, 1996) and okra (Gupta, *et al.,* 2009; Kusal Roy *et al.,* 2017). Clothianidin is a novel thiazolyl ring possessing neonicotinoid insecticide with a good systemic action and high insecticidal activity against wide variety of insect species belongs to Hemiptera, Coleoptera, Thysanoptera, Lepidoptera and Diptera. Neonicotinoids act as nicotinic acetylcholine receptors (nAChR) agonists (Bai *et al.,* 1991; Yamamoto *et al.,* 1995). The "super agonist" action of clothianidin leads to its characteristic insecticidal properties (Vinothkumar *et al.,* 2017). Since the mode of action of clothianidin differs from that of organophosphates, carbamates, pyrethroids and IGRs, it can display a high level of activity against pest insects that have developed resistance to these existing compounds. Bioefficacy of the clothianidin was demonstrated against against pest of cumin (Suthar *et al.,* 2018), Sugarcane (Mane and Mohite, 2015; Vinothkumar *et al.,* 2018), chickpea (Adsure and Mohite, 2014), brinjal (Hemant Swami *et al.,* 2018), cotton (Rafee *et al.,* 2004; Patil *et al.,* 2007; Zhang *et al.,* 2017), Okra (Roy *et al.,* 2016), wheat (Zhang *et al.,* 2016) and castor (Duraimurugan and Alivelu, 2017). The formulation suspension concentrate (SC) has the advantages of both emulsifiable concentrate (EC) and wettable powder (WP). The microscopic particles of insecticide remain on the treated surface for easy pick-up by the insects. The formulation SC with lack of solvent has no staining or odour problems (Janaki, 2015). With this background knowledge, studies were conducted to assess the efficacy of the F9252 (bifenthrin 8% + clothianidin 10% SC) a ready mix formulation developed by M/s. FMC India Private Ltd, against white grub and sucking pests of groundnut.

MATERIAL AND METHODS

Two field trials were conducted at Tamil Nadu Agricultural University, Coimbatore during February to May 2016 and May - July 2017 using Groundnut variety TMV 7 in randomized block design (RBD) to evaluate the F9252 (bifenthrin 8 % + clothianidin 10 % SC) against insect pests of groundnut, toxicity to natural enemies and phytotoxicity effect, if any. Standard agronomic practices as per the recommendations of Tamil Nadu Agricultural University were followed to cultivate the groundnut crop. Applications of insecticides were made at the time of planting. The target dose rate was mixed in required quantity of water and sprayed (using pneumatic knapsack sprayer by removing nozzle) over the seeded rows for the insecticide to spread thoroughly around the seed zone (1000 litres of spray fluidwas used per ha). Second round of application was given at 30 days after sowing. The insecticides used in the present investigation and their dosages were, T_1 - Untreated control, T_2 - F9252 @ 60 + 75 g a.i. ha^{-1}, T_3 - F9252 @ 80 + 100 g a.i. ha^{-1}, T_4 - F9252 @ 100 + 125 g a.i. ha^{-1}, T_5 - Clothianidin @ 100 g a.i. ha^{-1}, T_6 - Clothianidin @ 125 g a.i. ha^{-1}, T_7 - Bifenthrin @ 80 g a.i. ha^{-1}, T_8 - Phorate 10 G @ 2500 g a.i. ha^{-1} and T_9 - Chlorpyrifos 20 EC @ 225g a.i. ha^{-1}. Per cent plant mortality due to white grub infestation was recorded in each plot from 15 days after sowing followed by subsequent observations at 15 days interval till harvest stage.

$$\text{Per cent plant mortality} = \frac{\text{(Number of plants dead)}}{\text{(Number of total plants per plot)}} \times 100$$

Work out the per cent control of plant mortality over untreated control was calculated using below formula,

$$\text{Per cent control of plant mortality} = \frac{\text{(Plant mortality in UTC - Plant mortality in Tr.)}}{\text{Plant mortality in UTC}} \times 100$$

Where, UTC-Untreated control, Tr.-Treatment

The populations of aphids were counted on top 2 cm shoot length of 5 randomly selected plants in each plot and thrips recorded by counting population on top three bud leaves of 5 randomly selected plants in each plot at before second application of insecticide and at 3, 5 and 10 days after second application. The per cent control of thrips and aphids population over untreated control was calculated using below formula

$$\text{Per cent control} = \frac{\text{(UTC population - Tr. population)}}{\text{UTC population}} \times 100$$

Where, UTC-Untreated control and Tr.-Treatment

Assessment of the phytotoxic effect of F9252 at X, 2X and 4X doses on groundnut crop was evaluated by conducting field experiment in a randomized block design with three replications and the plot size of 40m^2. Symptoms of phytotoxicity *viz.,* leaf injury, wilting, vein clearing, necrosis, yellowing, stunting, epinasty and hyponasty were observed from at 5, 10, 15, 20 and 30 days after second application as per Central Insecticide Board Registration Committee (CIBRC) protocol. Phytotoxicity symptoms was assessed on visual rating from 0-10 *viz*., 0 - No phytotoxicity; 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 % and 10 - 91-100 %. Per cent leaf injury was calculated using the formulae

$$\text{Per cent leaf injury} = \frac{\text{Total grade points}}{\text{Max. grade X No. of leaves observed}} \text{ X } 100$$

Groundnut yield data per plot were recorded in kg and presented in quintals per hectare. The corrected per cent reduction of pest population over control in the field was worked out by using the formula given by Henderson and Tilton (1955).

$$\text{Corrected per cent reduction} = \left(1 - \left[\frac{T_a \times C_b}{T_b \times C_a}\right]\right) \text{x } 100$$

where, T_a - Number of insects in the treatment after spraying; T_b - Number of insects in the treatment before spraying; C_b - Number of insects in the untreated check before spraying; C_a - Number of insects in the untreated check after spraying

The data on percentage were transformed into arc sine values and the population number into square root values before statistical analysis. The data obtained from field experiments were analysed in randomized block design (RBD) (Gomez and Gomez, 1984). The mean values were separated using Duncan's Multiple Range Test (DMRT) (Duncan, 1951).

RESULTS AND DISCUSSION

The results of the field studies conducted to assess the efficacy of the ready mix formulation F9252 (bifenthrin 8 % + clothianidin 10 % SC) against pests of groundnut revealed that, the infestation of white grub is started right from the emergence of the crop. The per cent plant mortality due to infestation of white grub at 15 days after sowing (DAS) was 6.28 per cent in the untreated control during first season (Table 1). F9252 @ 100 + 125 g a.i. ha^{-1} was recorded minimum damage of 0.92 per cent followed by F9252 @ 80 + 100 g a.i. ha^{-1} and 60 + 75 g a.i. ha^{-1} recorded 0.98 and 1.81 per cent, respectively. Clothianidin as solo spray @ 125 and 100 g a.i. ha^{-1} recorded more than 2 per cent damage which is on par with bifenthrin @ 80 g a.i. ha^{-1}, phorate 10 G @ 2500 g a.i. ha^{-1}, chlorpyrifos 20 EC @ 225 g a.i. ha^{-1} on 15 DAS. Same trend was observed 30 DAS. On 45 DAS or 15 days after second dose, the damage level was reduced in the insecticide treated plots. The per cent plant mortality due to white grub infestation is less than 1 per cent at the plots treated with F9252 @ 100 + 125 g a.i. htha^{-1} and F9252 @ 80 + 100 g a.i. ha^{-1}.

Table 1. Efficacy of F9252 against white grub infestation in groundnut (I Season)

Treatments	Per cent plant mortality due to white grub infestation								
	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	105 DAS	Mean	PRC
Untreated control	6.28 (14.46)	7.33 (15.66)	8.55 (16.95)	10.39 (18.74)	12.02 (20.23)	13.43 (21.44)	14.73 (22.51)	10.39 (18.80)^d	-
F9252 @ 60 + 75 g a.i. ha^{-1}	1.81 (7.71)	2.47 (9.02)	2.08 (8.27)	3.08 (10.08)	4.12 (11.68)	5.29 (13.26)	7.05 (15.35)	3.70 (11.09)^b	64.39
F9252 @80 + 100g a.i. ha^{-1}	0.98 (5.67)	1.42 (6.82)	0.77 (5.04)	1.45 (6.90)	2.22 (8.54)	3.14 (10.18)	4.19 (11.78)	2.02 (8.18)^a	80.52
F9252 @100 + 125g a.i. ha^{-1}	0.92 (5.48)	1.32 (6.59)	0.71 (4.83)	1.33 (6.61)	2.00 (8.11)	2.91 (9.80)	4.08 (11.63)	1.90 (7.91)^a	81.75
Clothianidin @100g a.i. ha^{-1}	2.67 (9.39)	3.65 (10.99)	3.44 (10.67)	4.92 (12.79)	6.48 (14.72)	8.14 (16.54)	9.67 (18.08)	5.57 (13.64)^c	46.42
Clothianidin @ 125g a.i. ha^{-1}	2.44 (8.97)	3.28 (10.41)	3.09 (10.10)	4.70 (12.49)	5.94 (14.07)	7.82 (16.19)	9.35 (17.75)	5.23 (13.22)^c	49.65
Bifenthrin @ 80g a.i. ha^{-1}	2.43 (8.96)	3.21 (10.32)	2.87 (9.75)	4.21 (11.83)	5.51 (13.56)	7.39 (15.76)	9.04 (17.48)	4.95 (12.85)^c	52.34
Phorate 10 G @ 2500g a.i. ha^{-1}	2.96 (9.88)	3.79 (11.20)	3.71 (11.09)	5.33 (13.33)	6.93 (15.24)	8.57 (16.99)	9.99 (18.40)	5.90 (14.05)^c	43.24
Chlorpyrifos 20 EC @ 225g a.i. ha^{-1}	1.85 (7.81)	2.56 (9.19)	2.17 (8.47)	3.29 (10.44)	4.30 (11.95)	5.41 (13.44)	7.17 (15.51)	3.82 (11.27)^b	63.22
S.Em.	0.32	0.36	0.36	0.42	0.47	0.51	0.56	0.43	-
CD at 0.05	0.95	1.07	1.09	1.26	1.40	1.54	1.69	1.29	-

DAS- Days after Sowing; PRC - Per cent reduction over control; Values in parentheses are arcsine transformed values; In a column means followed by a common letter are not significantly different by DMRT (P=0.05)

Whereas in the untreated control plots the per cent plant mortality is in increasing trend. The mortality of the plants due to white grub at the time of harvest were 14.73 per cent in untreated control followed by 9.99 per cent in phorate 10 G @ 2500 g a.i. ha^{-1}, 9.67 per cent in clothianidin @ 125 g a.i. ha^{-1} and 9.67 per cent in clothianidin @ 100 g a.i. ha^{-1} and 9.07 per cent in phorate 10 G @ 2500 g a.i. ha^{-1} (Table 1).

Table 2. Efficacy of F9252 against white grub infestation in groundnut (II Season)

Treatments	Per cent plant mortality due to white grub infestation								
	15 DAS	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	105 DAS	Mean	PRC
Untreated control	5.92 (14.04)	6.96 (15.24)	8.07 (16.45)	10.20 (18.57)	12.32 (20.48)	13.14 (21.19)	14.36 (22.21)	10.14 (18.56)[d]	-
F9252 @ 60 + 75 g a.i. ha^{-1}	1.54 (7.10)	2.16 (8.42)	1.78 (7.65)	2.79 (9.59)	3.80 (11.20)	4.97 (12.85)	6.71 (14.97)	3.39 (10.61)[b]	66.54
F9252@80 + 100g a.i. ha^{-1}	0.73 (4.90)	1.11 (6.03)	0.54 (4.19)	1.13 (6.08)	2.14 (8.40)	2.71 (9.46)	3.90 (11.37)	1.75 (7.60)[a]	82.73
F9252@100 + 125g a.i. ha^{-1}	0.61 (4.47)	1.02 (5.78)	0.45 (3.85)	0.99 (5.71)	1.68 (7.43)	2.61 (9.29)	3.73 (11.13)	1.58 (7.23)[a]	84.37
Clothianidin @100g a.i. ha^{-1}	2.32 (8.74)	3.35 (10.52)	3.17 (10.24)	4.50 (12.23)	6.38 (14.60)	7.91 (16.30)	9.33 (17.75)	5.28 (13.28)[c]	47.92
Clothianidin @ 125g a.i. ha^{-1}	2.14 (8.40)	3.05 (10.04)	2.86 (9.72)	4.25 (11.86)	6.02 (14.17)	7.40 (15.75)	9.02 (17.44)	4.96 (12.87)[c]	51.05
Bifenthrin @ 80g a.i. ha^{-1}	2.10 (8.32)	2.89 (9.78)	2.60 (9.27)	4.02 (11.55)	5.94 (14.10)	6.91 (15.22)	8.47 (16.90)	4.70 (12.52)[c]	53.60
Phorate 10 G @ 2500g a.i. ha^{-1}	2.46 (9.00)	3.38 (10.58)	3.28 (10.41)	4.74 (12.56)	6.40 (14.64)	8.06 (16.47)	9.68 (18.10)	5.43 (13.47)[c]	46.46
Chlorpyrifos 20 EC @ 225g a.i. ha^{-1}	1.62 (7.31)	2.19 (8.50)	1.97 (8.05)	3.00 (9.97)	3.97 (11.47)	5.19 (13.16)	6.81 (15.11)	3.54 (10.83)[b]	65.13
S.Em.	0.31	0.35	0.37	0.43	0.49	0.53	0.58	0.44	-
CD at 0.05	0.93	1.06	1.10	1.28	1.47	1.60	1.74	1.31	-

DAS- Days after Sowing; PRC - Per cent reduction over control; Values in parentheses are arcsine transformed values; In a column means followed by a common letter are not significantly different by DMRT (P=0.05)

Mean per cent reduction of plant mortality over untreated control was calculated and results revealed that, F9252 @ 100 + 125 g a.i. ha^{-1} and 80 + 100 g a.i. ha^{-1} registered high level of per cent reduction of mortality of plants (More than 80 %) over untreated control (Table 1). Clothianidin and bifenthrin as solo treatment registered less than 53 per cent reduction of plant mortality over untreated control.

Table 3. Efficacy of F9252 against aphid infestation in groundnut

Treatments	I Season						II Season					
	PTC	3 DAT	5 DAT	10 DAT	Mean	PRC	PTC	3 DAT	5 DAT	10 DAT	Mean	PRC
Untreated control	34.07 (5.86)	36.40 (6.06)	37.93 (6.18)	40.47 (6.38)	38.27 (6.23)[d]	-	30.27 (5.53)	31.80 (5.67)	33.40 (5.81)	36.13 (6.04)	33.78 (5.85)[d]	-
F9252 @ 60 + 75 g a.i. ha^{-1}	32.13 (5.70)	9.93 (3.22)	14.20 (3.83)	19.47 (4.46)	14.53 (3.88)[b]	62.02	28.00 (5.33)	7.47 (2.82)	11.40 (3.44)	16.07 (4.06)	11.65 (3.49)[b]	65.52
F9252 @80 + 100g a.i. ha^{-1}	32.60 (5.74)	4.07 (2.13)	6.40 (2.62)	11.80 (3.50)	7.42 (2.81)[a]	80.60	29.80 (5.49)	3.60 (2.02)	7.00 (2.73)	10.13 (3.25)	6.91 (2.72)[a]	79.54
F9252 @100 + 125g a.i. ha^{-1}	33.67 (5.84)	3.40 (1.97)	5.80 (2.51)	11.00 (3.39)	6.73 (2.69)[a]	82.40	28.33 (5.37)	3.20 (1.92)	6.60 (2.66)	9.87 (3.22)	6.56 (2.66)[a]	80.59
Clothianidin @100g a.i. ha^{-1}	32.33 (5.72)	11.00 (3.39)	15.80 (4.03)	21.60 (4.69)	16.13 (4.08)[b]	57.84	30.13 (5.53)	8.00 (2.91)	12.20 (3.56)	17.33 (4.22)	12.51 (3.61)[b]	62.96
Clothianidin @ 125g a.i. ha^{-1}	33.47 (5.81)	10.40 (3.29)	15.00 (3.93)	20.80 (4.60)	15.40 (3.99)[b]	59.76	29.73 (5.49)	7.80 (2.87)	11.93 (3.52)	16.87 (4.16)	12.20 (3.56)[b]	63.88
Bifenthrin @ 80g a.i. ha^{-1}	32.67 (5.76)	23.00 (4.84)	26.00 (5.14)	31.40 (5.64)	26.80 (5.22)[c]	29.97	29.67 (5.49)	18.60 (4.37)	20.40 (4.57)	25.93 (5.14)	21.64 (4.71)[c]	35.92
Phorate 10 G @ 2500g a.i. ha^{-1}	31.27 (5.63)	18.27 (4.33)	23.60 (4.90)	29.00 (5.42)	23.62 (4.91)[c]	38.27	27.93 (5.33)	15.20 (3.96)	19.93 (4.51)	25.40 (5.08)	20.18 (4.55)[c]	40.26
Chlorpyrifos 20 EC @ 225g a.i. ha^{-1}	31.73 (5.67)	19.40 (4.46)	24.73 (5.02)	29.87 (5.51)	24.67 (5.02)[c]	35.54	28.00 (5.33)	16.20 (4.08)	21.00 (4.63)	26.33 (5.18)	21.18 (4.66)[c]	37.30
S.Em.	-	0.14	0.15	0.16	0.15	-	-	0.12	0.13	0.15	0.13	-
CD at 0.05	NS	0.41	0.44	0.48	0.44	-	NS	0.37	0.40	0.45	0.41	-

PTC- Pretreatment count; DAT- Days after treatment; PRC - Per cent reduction over control; Values in parentheses are $\sqrt{x+0.5}$ transformed values. In a column means followed by a common letter are not significantly different by DMRT (P=0.05)

During second season 15 DAS count registered between 0.61 to 5.92 per cent. Minimum mortality of the plant noticed in the plots treated with insecticides (Table 2). The mean per cent mortality was 1.58 per cent in the F9252 @ 100 + 125 g a.i. ha^{-1} treated plots and it was on par with the F9252 @ 80 + 100 g a.i. ha^{-1} (1.75 per cent). F9252 @ 60 + 75 g a.i. ha^{-1} and chlorpyrifos 20 EC @ 225g a.i. ha^{-1} were on in controlling the plant mortality due to white grub (3.39 and 3.54 per cent, respectively).

Table 4. Efficacy of F9252 against thrips infestation in groundnut

Treatments	I Season						II Season					
	PTC	3 DAT	5 DAT	10 DAT	Mean	PRC	PTC	3 DAT	5 DAT	10 DAT	Mean	PRC
Untreated control	11.27 (3.42)	13.00 (3.66)	15.47 (3.99)	18.07 (4.30)	15.51 (4.00)^{e}		8.13 (2.93)	9.93 (3.22)	11.33 (3.43)	14.20 (3.82)	11.82 (3.51)^{e}	
F9252 @ 60 + 75 g a.i. ha^{-1}	10.20 (3.26)	3.20 (1.92)	4.93 (2.33)	7.93 (2.90)	5.35 (2.42)^{b}	65.49	7.40 (2.80)	2.53 (1.74)	3.40 (1.97)	6.07 (2.56)	4.00 (2.12)^{b}	66.16
F9252@80 + 100g a.i. ha^{-1}	10.47 (3.31)	1.93 (1.56)	3.40 (1.97)	6.20 (2.58)	3.84 (2.08)^{a}	75.23	8.93 (3.07)	1.47 (1.40)	2.53 (1.74)	4.67 (2.27)	2.89 (1.84)^{a}	75.55
F9252@100 + 125g a.i. ha^{-1}	10.87 (3.37)	1.60 (1.45)	3.13 (1.90)	5.87 (2.52)	3.53 (2.01)^{a}	77.22	9.20 (3.11)	1.20 (1.30)	2.20 (1.64)	4.33 (2.20)	2.58 (1.75)^{a}	78.20
Clothianidin @100g a.i. ha^{-1}	11.33 (3.43)	3.53 (2.00)	5.33 (2.41)	8.27 (2.96)	5.71 (2.49)^{b}	63.19	9.00 (3.08)	2.80 (1.81)	4.00 (2.12)	6.20 (2.58)	4.33 (2.20)^{b}	63.34
Clothianidin @ 125g a.i. ha^{-1}	11.07 (3.39)	3.33 (1.95)	5.13 (2.37)	8.00 (2.91)	5.49 (2.45)^{b}	64.63	7.80 (2.87)	2.67 (1.78)	3.67 (2.04)	6.13 (2.57)	4.16 (2.16)^{b}	64.83
Bifenthrin @ 80g a.i. ha^{-1}	10.40 (3.30)	8.93 (3.07)	11.13 (3.41)	14.20 (3.83)	11.42 (3.45)^{d}	26.39	9.07 (3.09)	6.47 (2.64)	8.33 (2.97)	11.00 (3.39)	8.60 (3.02)^{d}	27.24
Phorate 10 G @ 2500g a.i. ha^{-1}	11.67 (3.48)	5.93 (2.53)	8.40 (2.98)	12.07 (3.54)	8.80 (3.05)^{c}	43.27	8.33 (2.97)	4.33 (2.20)	5.93 (2.53)	8.80 (3.05)	6.35 (2.62)^{c}	46.25
Chlorpyrifos 20 EC @ 225g a.i. ha^{-1}	11.27 (3.43)	6.33 (2.61)	9.00 (3.08)	12.93 (3.66)	9.42 (3.15)^{c}	39.28	8.60 (3.01)	4.87 (2.32)	6.33 (2.61)	9.80 (3.21)	7.00 (2.74)^{c}	40.78
S.Em.	-	0.08	0.09	0.10	0.09		-	0.07	0.08	0.09	0.08	
CD at 0.05	NS	0.23	0.27	0.31	0.27		NS	0.20	0.23	0.27	0.24	

PTC- Pretreatment count; DAT- Days after treatment; PRC - Per cent reduction over control; Values in parentheses are $\sqrt{x+0.5}$ transformed values In a column means followed by a common letter are not significantly different by DMRT (P=0.05)

All other insecticide tested viz., bifenthrin @ 80 g a.i. ha^{-1}, clothianidin @ 125 g a.i. ha^{-1}, clothianidin @ 100 g a.i. ha^{-1} and phorate 10 G @ 2500 g a.i. ha^{-1} were recorded mean per cent mortality of 4.70, 4.96, 5.28 and 5.43 per cent, respectively and on par with each other. Based on per cent reduction of plant mortality over untreated control the order of relative efficacy of the test insecticides in controlling the white grub were, F9252 @ 100 + 125 g a.i. ha^{-1} > F9252 @ 80 + 100 g a.i. ha^{-1} > F9252 @ 60 + 75 g a.i. ha^{-1} > chlorpyrifos 20 EC @ 225g a.i. ha^{-1} > bifenthrin @ 80 g a.i. ha^{-1} > clothianidin @ 125 g a.i. ha^{-1} > clothianidin @ 100 g a.i. ha^{-1} > phorate 10 G @ 2500 g a.i. ha^{-1} (Table 2).

Table 5. Phytotoxic effect of F9252 on groundnut

Treatments	Phytotoxicity rating *					
	Leaf tip injury	Wilting	Vein clearing	Necrosis	Epinasty	Hyponasty
Untreated Control	0	0	0	0	0	0
F9252 @ 80 + 100 g a.i. ha^{-1}	0	0	0	0	0	0
F9252 @ 160 + 200 g a.i. ha^{-1}	0	0	0	0	0	0
F9252 @ 240 + 300 g a.i. ha^{-1}	0	0	0	0	0	0

* Observed on 5, 10, 15, 20 and 30 days after treatment

The aphid populations varied from 31.27 to 34.07 per plant with non significant differences among various treatments at one day before imposing the second application. On 3 day after second application (DAA) population of aphid were reduced to minimum in all the insecticides compared to untreated control and increased population was noticed in the subsequent observations. Mean population of aphids during first season was minimum in the plots treated with F9252 at 100+125 g a.i. ha^{-1} (6.73 aphids per plant) and it was on par with F9252 at 80+100 g a.i. ha^{-1} (7.42 aphids per plant) . F9252 at 60+75 g a.i. ha^{-1}, clothianidin @ 125 g a.i. ha^{-1} and clothianidin @ 100 g a.i. ha^{-1} were on par with each other in controlling aphids in groudnut and recorded 14.53, 15.40 and 16.13 aphids per plant, respectively and all the insecticidal treatments were showing superior in controlling aphid than untreated control. The data on per cent control of aphids indicated that highest per cent control of aphids in groundnut was recorded in the treatments like, F9252 at 100+125 g a.i. ha^{-1} and F9252 at 80+100 g a.i. ha^{-1} and these two treatments were comparatively

superior to all other treatments (Table 3). During second season, the mean population of aphids on a day before imposing of second round of insecticide treatments was varied from 27.93 to 30.27 and found non significant variation among treatments. Based on per cent reduction of aphid populations over untreated control the order of relative efficacy of the test insecticides in controlling the aphids were, F9252 @ 100 + 125 g a.i. ha^{-1} (80.59 %) = F9252 @ 80 + 100 g a.i. ha^{-1} (79.54 %) > F9252 @ 60 + 75 g a.i. ha^{-1} (65.52 %) = clothianidin @ 125 g a.i. ha^{-1} (63.88 %) = clothianidin @ 100 g a.i. ha^{-1} (62.96 %) > phorate 10 G @ 2500 g a.i. ha^{-1} (40.26 %) = chlorpyrifos 20 EC @ 225g a.i. ha^{-1} (37.30 %) = bifenthrin @ 80 g a.i. ha^{-1} (35.92 %) (Table 3).

Table 6. Effect of F9252 on groundnut yield

Treatments	Pod yield (q ha^{-1})			
	I Season	II Season	Mean	PIC
Untreated control	7.71	8.44	8.08^{c}	-
F9252 @ 60 + 75 g a.i. ha^{-1}	11.00	12.15	11.58^{b}	43.34
F9252 @ 80 + 100g a.i. ha^{-1}	13.95	15.15	14.55^{a}	80.19
F9252 @ 100 + 125g a.i. ha^{-1}	14.16	15.41	14.79^{a}	83.10
Clothianidin @ 100g a.i. ha^{-1}	9.78	10.57	10.18^{b}	26.01
Clothianidin @ 125g a.i. ha^{-1}	10.15	11.20	10.68^{b}	32.20
Bifenthrin @ 80 g a.i. ha^{-1}	9.70	10.48	10.09^{bc}	24.95
Phorate 10 G @ 2500g a.i. ha^{-1}	11.33	12.38	11.86^{b}	46.81
Chlorpyrifos 20 EC @ 225g a.i. ha^{-1}	9.81	10.70	10.26^{b}	27.00
S.Em.	**0.66**	**0.68**	**0.67**	-
CD at 0.05	**1.98**	**2.03**	**2.01**	-

PIC – per cent Increase over control. In a column means followed by a common letter are not significantly different by DMRT (P=0.05)

The bioefficacy of F9252 against thrips is presented in Table 4. The pre-treatment population (Before imposing second round of soil drenching of insecticide) varied from 10.20 to 11.67 per plant during first season and 7.80 to 9.20 per plant during second season. F9252 at 100 + 125 g a.i. ha^{-1} reduced the thrips population significantly and the mean population during first season was 3.53 per plant and it was on par with F9252 @ 80 + 100 g a.i. ha^{-1} (3.84 per plant). F9252 @ 60 + 75 g a.i. ha^{-1} recorded 5.35 thrips per plant, followed by clothianidin @ 125 g a.i. ha^{-1} (5.49 per plant) and clothianidin @ 100 g a.i. ha^{-1} (5.71 per plant). Phorate 10 G @ 2500 g a.i. ha^{-1}, chlorpyrifos 20 EC @ 225g a.i. ha^{-1} and bifenthrin @ 80 g a.i. ha^{-1} recorded 8.80, 9.42 and 11.42 thrips per plant, respectively, whereas population in untreated control was 15.51 per plant. During second season also, F9252 @ 100 + 125 g a.i. ha^{-1}, F9252 @ 80 + 100 g a.i. ha^{-1} recorded very low mean population of 2.58 and 2.89 thrips per plant, respectively. The order of relative efficacy based on per cent reduction of thrips over control was, F9252 @ 100 + 125 g a.i. ha^{-1} = F9252 @ 80 + 100 g a.i. ha^{-1} > F9252 @ 60 + 75 g a.i. ha^{-1} = clothianidin @ 125 g a.i. ha^{-1} = clothianidin @ 100 g a.i. ha^{-1} > phorate 10 G @ 2500 g a.i. ha^{-1} = chlorpyrifos 20 EC @ 225g a.i. ha^{-1} > bifenthrin @ 80 g a.i. ha^{-1} (Table 4).

The phytotoxicity of F9252 as soil drenching to the groundnut crop with TMV 6 variety was assessed by recording visual observations, *viz*., injury to leaf tip and leaf surface, wilting, vein clearing, necrosis, epinasty and hyponasty (Table 5). The results indicated that F9252 at 80 + 100, 160 + 200 and 240 + 300 g a.i. ha^{-1} did not cause any visual phytotoxic symptoms in both the season of experimentation. All the insecticide treatments recorded significantly higher yield (10.18 to 14.79 q ha^{-1}) compared to untreated check (8.08 q ha^{-1}) in two season field experiments (Table 6). F9252 @ 100 + 125g a.i. ha^{-1} recorded the yield of 14.16 and 15.41 q ha^{-1}, respectively in the first and second season field experiments, which was on par with F9252 @ 80 + 100g a.i. ha^{-1} (13.95 and 15.15 q ha^{-1} at first and second season, respectively). F9252 @ 60 + 75 g a.i. ha^{-1} recorded mean yield of 11.58 q ha^{-1} which is on par with all other test insecticides (Table 6).

F9252 (bifenthrin 8% + clothianidin 10% SC) a synthetic pyrethroids and neonicotinoid combination product given excellent control of white grub, aphids and thrips in groundnut and did not cause any phytotoxicity up to four folds of the recommended dose. Results of the present study is in accordance with Vinothkumar *et al.,* (2017) who reported that soil drenching of F9252 at 100+125 g a.i. ha^{-1} and

80+100 g a.i. ha^{-1} has been effectively controlled the termites and early shoot borer infestation in sugarcane ecosystem. Pyriproxyfen 8.0 SE + Clothianidin 3.5 SE @ 52.5+120 g a.i. /ha showed maximum mortality in whitefly and other sap sucking insect pests in brinjal (Hemant Swami *et al.,* 2018). Clothianidin seed treatments (at the rate of 4 g ai/ kg seed) combined with a clothianidin granular treatment (even at low rate of 0.9 kg ai/ha) at the bud stage can effectively suppress *A. gossypii* and *A. lucorum* infestations throughout the seedling and blooming stages of Bt cotton within 124 days after planting and can improve cotton yield (Zhang *et al.,* 2017). Clothianidin provided 99.2 and 95.1 per cent reduction in leafhopper (*Empoasca flavescens*) and thrips (*Retithrips syriacus*) population in castor. The maximum net return (Rs. 16068/ha) and benefit-cost ratio (1.70) was obtained with application of clothianidin followed by acetamiprid (Rs. 13548/ha and 1.62) and profenofos (Rs. 13443/ha and 1.61) (Duraimurugan and Alivelu, 2017). Clothianidin seed treatment have the potential to provide significant whole-plant protection against wheat aphids and prevent yield losses in winter wheat in the field (Zhang *et al.,* 2015). Clothianidin 50% WDG @ 20 and 25 gai/ha rendered very good protection of crop against the early season sucking pests of cotton and there was no phytotoxicity of clothianidin 50% WDG treatments at X and 2X dose on the cotton (Patil *et al.,* 2007). Seed treatment of cotton with clothianidin @ 12 ml per kg of seed effectively controlled the early stage sucking pest incidence up to 8 weeks after sowing and significantly high yield was recorded in the clothianidin treated plots (Dhandapani *et al.,* 2002; Udikeri *et al.,* 2007)

Bifenthrin 8 SC @ 100 to 140g a.i./ha was found significantly contol the population of *Earias vittella* and red spider mite (*Tetranychus urticae*) on okra (Kusal Roy et al., 2017). Roy *et al.,* (2016) reported that clothianidin @ 60g a.i./ha was found superior over other doses of clothianidin, carbofuran and thiamethoxam in controlling jassid population and in achieving maximum fruit yield of okra. Veeravel and Ravivarman (2010) reported that, bifenthrin 10 EC @ 75 g ai/ha was the most effective against rice stem borer *Scirpophaga incertulas* Walker, leaf folder *Cnaphalocrocis medinalis* Guenee and green leaf hopper *Nephotettix virescens* Distant and no phytotoxicity was observed in the above dose on rice. Bifenthrin @ 1000 ml/ha recorded 67.54, 79.76, 84.83 and 81.56 per cent reduction of leafhoppers, thrips, aphids and whiteflies, respectively in cotton (Balakeishnan *et al.,* 2009). Chinniah and Ali, (2000) reported that bifenthrin 10 WP (0.015%) was effective in controlling okra aphid. Jech and Husman (1998) found good control of whiteflies, thrips, mites and jassids using bifenthrin10 EC on okra.

CONCLUSION

The results of the two field experiments conducted to assess the efficacy of the ready mix formulation of F9252 (bifenthrin 8 % + clothianidin 10 % SC) against pests of groundnut revealed that, plots treated with F9252 @ 100 + 125 g a.i. ha^{-1} was recorded minimum damage of white grub and maximum control of aphid and thrips followed by F9252 @ 80 + 100 g a.i. ha^{-1}. The groundnut pod yield was maximum in the F9252 @ 100 + 125 g a.i. ha^{-1} and which was statistically on par with the yield of F9252 @ 80 + 100 g a.i. ha^{-1}. Hence, F9252 @ 80 + 100 g a.i. ha^{-1} is recommended to get maximum yield with effective control of groundnut pests in the comparatively low dose of insecticide exposure to the environment.

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