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Evaluation of bioefficacy of flubendiamide 24% w/v + thiacloprid 24% SC w/v against shoot and fruit borer and its sucking pests and its safety to non-target organisms in brinjal

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Abstract
The present field experiment to evaluate bioefficacy of flubendiamide 24% w/v + thiacloprid 24% sc w/v against shoot and fruit borer and sucking pests and its safety to non target organisms in brinjal was conducted during July – October 2015 and January – May 2016 at Tamil Nadu Agricultural University, Coimbatore, Tamil Nadu. Results revealed that, among the treatments, flubendiamide 24% + thiacloprid 24% SC w/v @ 84 + 84 g a.i ha^{-1} had incredible reduction of shoot and fruit borer and sucking pests. The mean per cent reduction over control of two consecutive seasons was recorded as 96.62 and 98. 25 per cent, respectively for shoot and fruit borer in flubendiamide 24%+thiacloprid 24% SC w/v @ 84 + 84 g a.i ha^{-1}, followed by flubendiamide 24% + thiacloprid 24% SC w/v @ 72 + 72 g a.i ha^{-1} (88.98 and 88.90 per cent, respectively) and thiaclorid 21.7% SC w/w @ 180 g a.i ha^{-1} (85.86 and 88.33 per cent, respectively). Regarding sucking pests, similarly the combination product @ 84 + 84 g ai ha^{-1} was highly effective in reducing aphids, jassids and thrips population (95.60, 95.33 and 91.88 per cent, respectively) followed by flubendiamide 24% w/v + thiacloprid 24% SC w/v @ 72+72 (87.79, 87.72 and 84.45 per cent, respectively) and 64 + 64 g ai ha^{-1} (80.89, 78.65 and 75.41 per cent, respectively). The highest fruit yield was recorded in flubendiamide 24% w/v + thiacloprid 24 % SC w/v @ 84 + 84 g a.i. ha-1 (47.92 t ha^{-1}) and also found relatively safer to non target organisms like spiders and coccinellids.

Keywords: Flubendiamide, thiacloprid, shoot and fruit borer, jassids, aphids and thrips

1. Introduction

Brinjal known as “King of vegetables” is the most common solanaceous vegetable grown in India [32]. This vegetable crop is significantly grown by small and marginal farmers and it is an important source of income for them. The production statistics of 2014-15 divulged that brinjal is cultivated in 6, 80,000 ha with productivity of 12, 706, 000 tonnes [1]. On the subject of health benefits, it is known as one of the ten sources of the world’s healthiest food [2, 3]. They are made up of a host of vitamins and minerals, dietary fibre, proteins, antioxidants, as well as phytochemicals that possess antioxidant activity [4, 5, 6]. The major phytochemical found in eggplant is glucoside, phenolic compounds (caffeic, chlorogenic) and flavonoids (nasunin, delphindin) [7] and [8]. The crop suffers profound biotic stress throughout growth period and more than 30 insect pests are found to cause significant damage right from germination to harvest [9]. Of which shoot and fruit borer, Leucinodes orbonalis Guenee; jassid, Amrasca biguttula biguttula (Ishida); whitefly, Bemisia tabaci Gennadius, aphid, Aphis gossypii Glover, mites, Tetranychus cinnabarinus Boisdual and epilachna beetle, Henosepilachna vigintioctopunctata (Fab.) are considered to be significant in making yield loss. Amongst, shoot and fruit borer, Leucinodes orbonalis (Guen.) is devastating pest and yield loss due to infestation is estimated to extent of 70 to 92 per cent [10]. The management of insect pests by chemical means prove to be effective and solitary approach. Due to inopportune effects of conventional insecticides like organophosporous and organochlorines, novel groups viz., neonicotinoids, diamides that imparts potential selectivity towards target pest occupies predominance in pest management scenario for the past few years [33].

The pthalic acid diamide, named as flubendiamide [11] has an excellent biological and ecological profile [12, 13] and favourable toxicological profile [14]. Flubendiamide was classified as the first member of the new group 28 (ryanodine receptor modulator) insecticides within the

IRAC (Insecticide Resistance Action Committee) mode of action classification scheme [15]. Flubendiamide has larvicidal activity as a stomach poison. The primary route of exposure is oral ingestion and exhibits unique mode of action of targeting calcium ion balance in muscular system [16]. It is mainly effective for controlling lepidopteran pests including resistant strains in pulses, rice, cotton, corn, grapes and other fruits and vegetables [17]. Thiacloprid, belonging to neonicotinoid group is a relatively new chloronicotinyl insecticide (Bayer AG, Germany) that exhibits good plant compatibility and has proven to be an excellent insecticide against sucking and biting insects [18]. The use of insecticides as combination product with different modes of action and target may help in reduction enhancement of categories of pest. Furthermore, number of insecticide application would be reduced which may pave the opportunity for easy fit into the strategies of integrated pest management. With this scientific scope, two field experiments were conducted to evaluate bioefficacy of combination product flubendiamide 24% + thiacloprid 24% SC w/v against fruit and shoot borer and sucking insect pests and their safety towards non target organism in brinjal.

2. Materials and methods

Two field experiments were conducted at Tamil Nadu Agricultural University, Coimbatore during July – October 2015 and January – May 2016 (Variety: CO – 2). The experiment was laid out in Randomized Block Design with three replications. The treatment details were T1 - Flubendiamide 24% w/v + thiacloprid 24% SC w/v @ 60+60 g ai ha^{-1}, T2 - Flubendiamide 24% w/v + thiacloprid 24% SC w/v @ 72 + 72 g ai ha^{-1}, T3 - Flubendiamide 24% w/v + thiacloprid 24 % SC w/v @ 84 + 84 g ai ha^{-1}, T4 - Flubendiamide 39.35 % SC m/m

@ 90 g ai ha^{-1}, T5 - Thiacloprid 21.7 % SC w/w @ 84 g ai ha^{-1}, T6 - Thiacloprid 21.7 % SC w/w

@ 180 g ai ha^{-1}, T7 - Betacyfluthrin 8.49% + imidacloprid 19.81% OD w/w @ 18 + 42 g ai ha^{-1},

T8 - Deltametrin % + triazophos 35% EC @ 12.5 + 437.5 g ai ha^{-1}, T9 – Untreated control. The treatments were imposed on 48 days old crop and applied twice at weekly interval. The treatments were sprayed with pneumatic knapsack sprayer using 500 litres of spray fluid per hectare.

(i) Assessment of shoot and fruit borer damage

Number of shoots and fruits with typical round holes was observed and recorded separately from 5 randomly tagged plants at prior to insecticide application, 3 and 7 days after spray in each plot of three replications. The per cent shoot and fruit damage was worked out and result was expressed as per cent damage per plant.

$$\text{Shoot damage (\%)} = \frac{\text{Number of damaged shoots / 5 plants}}{\text{Total number of shoots / 5 plants}} \times 100$$

$$\text{Fruit damage (\%)} = \frac{\text{Number of damaged fruits / 5 plants}}{\text{Total number of fruits/ 5 plants}} \times 100$$

(ii) Assessment of population of sucking pests

Population of sucking pest's *viz.*, aphids, jassids and thrips was recorded on 10 leaves per plant of five randomly selected plants per plot prior to spraying followed by 3 and 7 after each spray and expressed as number per 10 leaves. Fruit yield per plot was recorded at time of harvest and pooled to express in t ha^{-1}.

(iii) Assessment of population of non – target organisms

The coccinellids and spiders were choosen as non target organisms which are naturally available in brinjal ecosystem. Five randomly selected plants per plot were thoroughly observed for population of natural enemies. The population of the predators (coccinellids and spiders) was recorded before and 3 and 7 days after each spraying and expressed as numbers per five plants.

(iv) Statistical analysis

The population of pest, predators and yield data was subjected to square root transformation before statistical analysis. Similarly, the per cent reduction of shoot and fruit borer damage was transformed to arc sine values. The transformed data was subjected to one way ANOVA for analysis of variation between treatments. The significant difference between treatments was judged by CD at 5% level of significance.

3. Results

(i) Bioefficacy against insect pests

The bioefficacy investigation results revealed that flubendiamide 24% w/v + thiacloprid 24 % SC w/v @ 84 + 84 g ai ha^{-1} was found to be effective in together reduction of shoot and fruit borer and jassids, aphids and thrips. Concerning the percent reduction of shoot damage, flubendiamide 24% w/v + thiacloprid 24 % SC w/v @ 84 + 84 g ai ha^{-1} recorded 96.62 mean per cent reduction over control (MPRC) of two consecutive seasons. Reduction of damage was also significant in next two lower subsequent doses @ 72 + 72 and 64 + 64 g ai ha^{-1} in which 88.98 and 78.75 MPRC was recorded. Noteworthy, application of thiacloprid 21.7% SC w/w @ 180 g ai ha^{-1} also marked the significant reduction as 85.86 MPRC. The standard check, betacyfluthrin 8.49% + imidacloprid 19.81% OD w/w @ 18 + 42 g ai ha^{-1} recorded 78.06 MPRC. Application of flubendiamide 39.35% SC m/m @ 90 g ai ha^{-1} alone reduced the damage level up to 70.89 MPRC. On the subject of fruit damage reduction, flubendiamide 24% w/v + thiacloprid 24 % SC w/v @ 84 + 84, 72 + 72 and 64 + 64 g ai ha^{-1} recorded 98.25, 88.90 and 80.57 MPRC respectively. The significant reduction was also observed in application of thiacloprid 21.7% SC w/w @ 180 g ai ha^{-1} alone (88.33 MPRC)(Table 1).
Besides, the combination of flubendiamide 24% w/v + thiacloprid 24 % SC w/v was effective in reducing jassids, aphids and thrips population. The combination product @ 84 + 84 g a.i ha^{-1} was highly effective in reducing aphids, jassids and thrips population (95.60, 95.33 and 91.88 MPRC, respectively) followed by flubendiamide 24% w/v + thiacloprid 24 % SC w/v @ 72 + 72 g a.i ha^{-1} (87.79, 87.72 and 84.45, respectively) and 64 + 64 g a.i ha^{-1} (80.89, 78.65 and 75.41 MPRC, respectively). The application of thiacloprid 21.7% SC w/w alone @ 180 and 84 g a.i ha^{-1} exhibited (79.80, 76.83 and 83.13, respectively) and (71.62, 67.99 and 74.63 MPRC, respectively). Regarding the yield, irrespective of treatments, increase in yield was noted compared to untreated control. The yield in all the treatments ranged from 40.54 to 47.92 t ha^{-1} whereas 39.80 t ha^{-1} was observed in untreated control. Among, treatment imposed with flubendiamide 24% w/v + thiacloprid 24% SC w/v @ 84 + 84 g a.i ha^{-1} recorded highest yield of 47.92 t ha^{-1} (Table 2).

(ii) Effect on non-target organisms and yield

The population of coccinellids and spiders were recorded from treatment and untreated control plots. The results revealed that all the treatments were relatively safer to coccinellids and spiders in brinjal ecosystem. The mean spider population of two season experiment was recorded as 6.29 and 6.23 five plants-1 in flubendiamide 24% w/v + thiacloprid 24 % SC w/v @ 60 + 60 g a.i ha^{-1} and thiacloprid 21.7% SC w/w @ 84 g a.i ha^{-1}, respectively next to untreated control (7.50 five plants-1). In the treatments, flubendiamide 24% w/v + thiacloprid 24 % SC w/v @ 72 + 72 and 84 + 84 g a.i ha^{-1} the mean population was observed as 5.33 and 4.57 five plants-1, whereas in the flubendiamide and thiacloprid alone applied treatments @ 90, 84 and 180 g a.i ha^{-1},the mean population was noted as 5.27, 6.23 and 5.28 five plants-1, respectively, In the plots treated with betacyfluthrin 8.49% + imidacloprid 19.81% OD w/w @ 18 + 42 g a.i ha^{-1}, deltamethrin 1% + triazophos 35% EC @ 12.5 + 437.5 g a.i ha^{-1}, mean population of 3.82 and 3.83 five plants-1 was recorded. Regarding coccinellids population, flubendiamide 24% w/v + thiacloprid 24 % SC w/v @ 60 + 60, 72 + 72 and 84 + 84 g a.i ha^{-1} recorded mean population of 6.41, 5.56 and 4.43 five plants-1, respectively subsequent to untreated control (7.83 five plants-1). The mean population of 5.33, 6.40 and 5.40 five plants-1 was noted in the standard checks, flubendiamide @ 90 g a.i ha^{-1} and thiacloprid @ 84 and 180 g a.i ha^{-1}, respectively. Further, betacyfluthrin 8.49% + imidacloprid 19.81% OD w/w @ 18 + 42 g ai ha^{-1}, deltamethrin 1% + triazophos 35% EC @ 12.5 + 437.5 g a.i ha^{-1} had mean population of 4.00 and 4.02 five plants-1, respectively.

The yield in all the treatments ranged from 40.54 to 47.92 t ha^{-1} whereas 39.80 t ha^{-1} was observed in untreated control. Among, treatment imposed with flubendiamide 24% w/v + thiacloprid 24 % SC w/v @ 84 + 84 g a.i ha^{-1} recorded highest yield of 47.92 t ha^{-1} (Table 3).

Table 1: Bioefficacy of flubendiamide 24% + thiacloprid 24% SC w/v against shoot and fruit borer damage in brinjal

T. No	Treatment	Dose (g a.i ha^{-1})	Per cent reduction over control					
			Per cent shoot damage			Per cent fruit damage		
			I Season	II Season	Mean	I Season	II Season	Mean
1.	Flubendiamide 24% + thiacloprid 24% SC w/v	60+60	79.47	78.03	78.75	77.58	83.55	80.57
2.	Flubendiamide 24% + thiacloprid 24% SC w/v	72+72	88.13	89.82	88.98	86.30	91.49	88.90
3.	Flubendiamide 24% + thiacloprid 24% SC w/v	84+84	95.60	97.64	96.62	98.09	98.40	98.25
4.	Flubendiamide 39.35% SC m/m	90	71.74	70.04	70.89	67.96	75.45	71.71
5.	Thiacloprid 21.7% SC w/w	84	63.82	59.05	61.44	57.19	65.56	61.38
6.	Thiacloprid 21.7% SC w/w	180	87.17	84.54	85.86	85.73	90.93	
7.	Betacyfluthrin 8.49% + imidacloprid 19.81% OD w/w	18+42	78.68	77.44	78.06	76.73	82.97	79.85
8.	Deltamethrin 1% + triazophos 35% EC	12.5+437.5	70.87	69.07	69.97	66.93	74.76	70.85
9.	Untreated control	-	-	-	-		-	-

Table 2: Bioefficacy of flubendiamide 24% + thiacloprid 24% SC w/v against sucking pests in brinjal

T. No	Treatment	Dose (g a.i ha^{-1})	Per cent reduction over control								
			Aphids			Jassids			Thrips		
			I Season	II Season	Mean	I Season	II Season	Mean	I Season	II Season	Mean
1.	Flubendiamide 24% + thiacloprid 24% SC w/v	60+60	81.16	80.62	80.89	79.73	77.57	78.65	78.09	72.72	75.41
2.	Flubendiamide 24% + thiacloprid 24% SC w/v	72+72	88.05	87.52	87.79	88.96	86.48	87.72	86.27	82.62	84.45
3.	Flubendiamide 24% + thiacloprid 24% SC w/v	84+84	97.05	94.14	95.60	97.04	94.82	95.93	92.97	90.78	91.88
4.	Flubendiamide 39.35% SC m/m	90	59.79	54.28	57.04	45.95	42.85	44.40	51.72	53.72	52.72
5.	Thiacloprid 21.7% SC w/w	84	70.10	73.14	71.62	70.42	65.56	67.99	77.24	72.01	74.63
6.	Thiacloprid 21.7% SC w/w	180	80.16	79.44	79.80	78.24	75.42	76.83	85.19	81.07	83.13
7.	Betacyfluthrin 8.49% + imidacloprid 19.81% OD w/w	18+42	79.32	79.20	79.26	77.06	74.08	75.57	76.91	71.04	73.98
8.	Deltamethrin 1% + triazophos 35% EC	12.5+437.5	68.28	73.05	70.67	69.46	63.97	66.72	69.87	62.60	66.24
9.	Untreated control	-	-	-		-	-		-	-	

Table 3: Effect of flubendiamide 24% + thiacloprid 24% SC w/v on non target organisms and yield in brinjal

T. No	Treatment	Dose (g a.i ha^{-1})	Per cent reduction over control						Yield (t ha^{-1})		
			Spiders			Coccinellids					
			I Season	II Season	Mean	I Season	II Season	Mean	I Season	II Season	Mean
1.	Flubendiamide 24% + thiacloprid 24% SC w/v	60+60	6.00	6.58	6.29	7.23	5.58	6.41	43.44	44.59	44.02
2.	Flubendiamide 24% + thiacloprid 24% SC w/v	72+72	5.08	5.58	5.33	6.25	4.87	5.56	46.08	47.69	46.89
3.	Flubendiamide 24% + thiacloprid 24% SC w/v	84+84	4.38	4.75	4.57	4.89	3.97	4.43	47.32	48.51	47.92
4.	Flubendiamide 39.35% SC m/m	90	5.04	5.49	5.27	6.00	4.66	5.33	42.56	43.76	43.16
5.	Thiacloprid 21.7% SC w/w	84	6.00	6.46	6.23	7.17	5.68	6.43	41.00	44.00	42.50
6.	Thiacloprid 21.7% SC w/w	180	4.99	5.57	5.28	6.04	4.76	5.40	43.09	44.27	43.68
7.	Betacyfluthrin 8.49% + imidacloprid 19.81% OD w/w	18+42	3.59	4.05	3.82	4.39	3.61	4.00	40.23	42.18	41.21
8.	Deltamethrin 1% + triazophos 35% EC	12.5+437.5	3.63	4.03	3.83	4.40	3.63	4.02	40.08	41.00	40.54
9.	Untreated control	-	7.06	7.94	7.50	8.57	7.08	7.83	39.54	40.05	39.80

4. Discussion

The above investigation results unveiled that the insecticides namely, flubendiamide and thiacloprid as an combined product relatively subdued shoot and fruit borer and sucking pests in brinjal than using as individual one. Flubendiamide, N2- (1,1 – dimethyl – 2 – methyl sulphonyl ethyl) – 3 – iodo – N1 – [2 – methyl – 4 – {1,2,2, 2 – tetrafluro – 1- (trifluro – methyl) ethyl} phenyl] 1,2 – benzene dicarboxamide insecticide having a unique structure and belongs to pthalic acid diamide group. The uniqueness of the structure results from three novel constituents: a heptafluroisopropyl group in the anilide moiety, a sulfonyalkyl group in the aliphatic amide moiety, and an iodine atom at the 3 – position of the pthalic acid moiety [16]. It acts by selective activation of the ryanodine receptor (RyR) in the endoplasmic reticulum of insects. The function of these specialized channels is the rapid release of Ca2+ from intracellular stores, which is necessary for muscle contraction. Diamide insecticides induce ryanodinesensitive cytosolic Ca2+ transients independent of the extracellular Ca2+ concentration [15, 14, 19, 20]. This potent activation of RyRs results in a fast initial efficacy in the insect larvae, with an unique symptomology of irreversible muscle contraction paralysis and characteristic feeding cessation [15].

The neonicotinoids act on postsynaptic nicotinic acetylcholine receptors (nAChRs). In insects, these receptors are located entirely in the CNS. Thiacloprid, [3-[(6-chloro-3-pyridinyl) methyl]-2-thiazolidinylidene] cyanamide, is a relatively new chloronicotinyl insecticide (Bayer AG, Germany) that exhibits good plant compatibility and has proven to be an excellent insecticide against sucking and biting insects [21]. Neonocotinoids act on at least three different subtypes of nAChRs, and cause a biphasic response, i.e., an initial increase in the frequency of spontaneous discharge followed by a complete block to nerve propagation.

In brinjal, the efficacy of flubendiamide 480 SC to manage shoot and shoot borer @ 90 and 72 g a.i. ha^{-1} has been reported [22]. The treatment recorded 11.43 and 16.21 per cent fruit infestation, respectively with highest fruit yield of 29.42 and 27.86 t ha^{-1}, respectively. Analogous finding was also recorded that flubendiamide 480 SC @ 0.1 ml l-1as an efficient management for shoot and fruit borer (11.83 and 11.66 per cent shoot and fruit damage, respectively) with highest BC ratio of 1: 5.42 [23]. Similarly, among different insecticides evaluation against sucking pests in brinjal, thiacloprid 0.012 per cent showed pronounced reduction in jassid population. The pooled mean over two sprays flaunted 3.74 jassis leaf-1 and recorded net ICBR as 56.10 [24]. Despite the fact that, efficacy of flubendiamide and thiacloprid has been reported individually in brinjal, the combination product has been evaluated in chilli against chilli thrips [25]. Flubendiamide 24% + Thiacloprid 24% -48% SC @ 48 + 48 g a.i./ha recorded least number of thrips and least leaf curl damage of 0.46 LCI/plant and significantly superior to comparative checks and recommended insecticide, Profenofos 50 EC @ 500 g a.i./ha and equally good as that of its higher dosage. The dry chilli yield was also better in Flubendiamide 24% + Thiacloprid 24% -48% SC @ 48 + 48 g a.i./ha (7.18 q/ha), which was equally good to its higher dosage and significantly superior to comparative checks and standard check of Profenofos 50 EC @ 500 g a.i/ha (5.77 q/ha). Our present investigation results are in assenting with the above said previous findings. The efficacy may be due to unique structure moiety of diamide groups that affects skeletal muscles of insects and causes rapid cessation of feeding and biphasic response of neonicotinoids.

On the subject of safety to non target organisms, both the chemicals, since belongs to the new chemistry, imparts potential selectivity and safer to use in field condition without causing interruption in function of non target organisms. The study had been conducted under laboratory condition for egg parasitoid, *T. cacoeciae* and a cereal aphid parasitoid, *Aphidius rhopalosiphi* [26]. The population was not affected by lethal or sublethal ways of thiacloprid 480 SC disclosing that the spray treatment of this insecticide in the field will not interfere with the pest control function of a parasitoid fauna in the target crops. Also, thiacloprid has been reported safe to the larvae of dipteran hoverfly, *Episyrphus balteaus* [27] on cotton and to adults of the predatory mite, *N. fallacis* in the laboratory. In tomato, flubendiamide 480 SC @ 48 g a.i ha^{-1} was highly effective in reducing fruit borer, *Helicoverpa armigera* Hubner but no adverse effects on non target organisms under field condition [28]. In brinjal, flubendiamide that was used to control shoot and fruit borer, *L. orbonalis* had been reported safer to spiders and lady bird beetles [29]. In studies regarding the harmful effects of the insecticides on the different life stages of *T. chilonis*, flubendiamide was found as the most selective and safe of all the tested insecticides for the development, survival and fecundity of the wasp [30]. Our present investigation is in confirmatory with the above findings that flubendiamide 24% + Thiacloprid 24% SC treatments were found to be relatively safer to spiders and coccinellids. Even if, diminutive reduction was noted in flubendiamide 24% + Thiacloprid 24% SC @ 84 + 84 g a.i. ha^{-1} compared to 72 + 72 and 60 + 60 g a.i. ha^{-1}, this may be correlated to density dependent nature of predator – prey relationship as described for mirid bug, the generalist predator of brown planthopper in rice. The mirid bug population was higher or lower with the more or less availability of BPH, respectively in dinotefuron and untreated rice plots [31].

5. Conclusion

In conclusion, flubendiamide and thiacloprid as a combined product recorded pronouncing efficacy against shoot and fruit borer and sucking pests in brinjal rather than applying as an individual treatments. Flubendiamide 24% + thiacloprid 24% @ 84 + 84 g a.i. ha^{-1} were found to be more effectual by recording above 90 per cent reduction of target pests and higher fruit yield. This combination of two molecules with different chemistry and targets was also safer to non – target organisms like spiders and coccinellids and does not interfere in their function of pest management.

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