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Neem Based IPM Modules for Control of *Sciothrips cardamomi* Ramk and *Conogethes punctiferalis* Gunee in Small Cardamom

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ABSTRACT

The bioefficacy of neem formulations, diafenthiuron and profenofos was tested individually and found effective against thrips *Sciothrips cardamomi* Ramk and shoot and capsule borer *Conogethes punctiferalis* Gunee in small cardamom. Based on the cost effectiveness, TNAU Neem oil 0.03 EC (1000 mL ha^{-1}), diafenthiuron 50 WP (600 g ai ha^{-1}) and profenofos 50 EC (500 mL ha^{-1}) were used to develop different IPM modules. Eleven IPM modules were evaluated and found to the sequential application of Neem, Diafenthiuron, Diafenthiuron, Profenofos and Profenofos (NDDPP) at 21 days interval was the most effective against *S. cardamomi* and the sequential application of Neem, Profenofos, Diafenthiuron, Neem and Profenofos (NPDNP) was the most effective against shoot and capsule borer *C. punctiferalis*. These IPM modules were more cost effective compared to other modules.

Key words: Cardamom, thrips, shoot borer, bioefficacy, integrated pest management, acute toxicity, settling behavior, ovipositional deterrence, diafenthiuron, profenofos

INTRODUCTION

Thrips, *Sciothrips cardamomi* Ramk. (Thysanoptera; Thripidae) and shoot and capsule borer *Conogethes punctiferalis* Guen. (Lepidoptera; Pyralidae) are two major pests of small cardamom grown in India. Thrips (nymphs and adults) infest blossom, young leaf sheath, panicle and capsule that causes scabby, aroma-less pods and yield loss of 52-60% (Ananthakrishnan, 1993). Shoot and capsule borer (larvae) infest shoot, stem and panicle and capsule that causes yield loss of 70-80% (Varadarasan, 2001).

At present, growers only depend on conventional insecticides to control these pests that pose the risk of pesticide hazards. Although, biological control and Integrated Pest Management (IPM) practices are very popular in several crops, practically a limited research works have been done to control cardamom pests. Hence, an IPM approach would be a good option where it uses all available pest control methods that combines means to reduce the status of pests to tolerable levels while maintaining a quality environment (Pedigo and Rice, 2008). The best approach would be to integrate strategies that fit individual field situations and that consider risk of cardamom yield loss versus cost of control while reducing negative environmental impact.

The neem could be an economically viable component in the IPM (Ermel *et al*., 2002), was found effective against several crop pests (Quarles, 1994; Akhtar *et al*., 2008), has less risk of developing resistance in insects (Feng and Ishman, 1995), was relatively nontoxic to mammals (Thoeming and

Poehling, 2006) and was less persistent in the environment. Furthermore, different neem formulations have been classified as safe for applications and safe for non-target organisms (Shmutterer, 1997; Rajabaskar and Regupathy, 2005).

Diafenthiuron (1-tert-butyl-3-(2,6-diisopropyl-4-phenoxyphenyl) thiourea) is a pro insecticide from thiourea derivative and found effective against aphid, whitefly and phytophagous mites (Vos *et al*., 1991; Cai, 1998; Chinnabbai *et al*., 2000). It has a novel mode of action (Ruder *et al*., 1991), is photo degradable (Keum *et al*., 2002), is less persistent in green and cured cardamom (Rajabaskar and Regupathy, 2008) and has phytotonic effect.

These are suited to include as an IPM component to control thrips and shoot borer in cardamom. Profenofos (O-4-bromo-2-chlorophenyl O-ethyl S-propyl phosphorothioate) is also a broad-spectrum insecticide with easy biodegradation in harvested produce (Renuka *et al*., 2006) and found effective against several crop pests (Patel *et al*., 1999; Rao *et al*., 1990; Sreekanth *et al*., 2000). Furthermore, several regional based IPM modules were developed to control the pests of cotton (Mohapatra, 2008), castor (Basappa, 2007), rice (Elakkiya *et al*., 2011), sugarcane (Rachappa *et al*., 2000), peanut (Rashmi *et al*., 2011) vegetables (Hooda *et al*., 2012; Mandal *et al*., 2009), mango (Singh *et al*., 2008) etc. and found successful. Hence, our research objective is to develop a cost effective IPM module using readily available pest management methods to control these pests. With this background, a study was undertaken to evaluate the bio efficacy of neem formulations, diafenthiuron and profenofos in laboratory as well as in field conditions to develop a cost effective IPM module for control of *S. cardamomi* and *C. punctiferalis* in small cardamom.

MATERIALS AND METHODS

Laboratory bioassays

Test insects: *C. punctiferalis:* Field collected larvae were reared on castor and ginger hosts using a plastic tray and it was kept under a mosquito net to avoid the escaping of adults. The daily-emerged adults from the host were sexed and caged separately. Five pairs of adults were released in to an ovipositional cage (60×30×45 cm) to lay eggs on ovipositional substrate. Cotton pad soaked with 10% sugar solution was provided as adult food. The oviposition substrate contained two plastic tea strainers put in juxtaposition (8 cm dia) containing host material as an odour source and was wrapped with khada cloth. This ovipositional substrate was kept inside the cage so as to hang from the upper side of the cage. The eggs laid on the khada cloth of ovipositional substrate were removed and utilized for further culturing of *C. punctiferalis*.

S. cardamomi: The selected plant was visually inspected for thrips infestation and tapped gently over a black cloth and transferred to a small Petri dish using an aspirator.

Feeding deterrence of neem formulations

***C. punctiferalis*:** A bunch of green cardamom capsules (50 g) was used for the multiple-choice test. The bunches were treated with different neem formulations (Nimbecidine 0.03%, Nimbecidine 0.15%, NeemAzal 1%, NeemAzal 5%, TNAU neem 0.03 EC), monocrotophos 0.072% and untreated check (water spray). The treated bunches were arranged randomly on filter paper in a circular fashion along the periphery of a plastic basin (40 cm dia) and this plastic basin was partially filled with moist sand. Batches of 50 larvae starved for three hours were released in to the centre of the basin and observations were made on number of larvae settled on the treated capsules 24 h after release. Each treatment was replicated for four times.

***S. cardamomi*:** Capsule dip bioassay method was followed; uniform size cardamom capsules were dipped in different neem formulations and monocrotophos by using a forceps. The treated capsules were dried on filter paper for 20 min and arranged randomly in a circular fashion along the periphery of the plastic tray (20 cm dia) by using a forceps. Using a fine zero point camel hairbrush, 25 thrips were transferred in to the center of the tray and covered with muslin cloth. Observations were made 24 h after release using a 10x hand lens. Each treatment was replicated for four times.

Ovipositional deterrence of neem formulations (*C. punctiferalis*): The ovipositional substrate containing 50 g of green cardamom capsules in the tea strainers was wrapped using white cotton cloth. Its outer side was sprayed with individual neem formulations (Nimbecidine 0.3%, Nimbecidine 0.15%, TNAU neem 0.03 EC, NeemAzal 1%, NeemAzal 5% at 2 mL L^{-1} of water) and monocrotophos 0.072%. An one liter plastic nursery knapsack sprayer was used to treat the ovipositional substrate and the treated substrates were hung randomly inside an ovipositional cage at 20 cm apart. The untreated check was treated with distilled water and 10 pairs of adult moths (male and female) were released into the ovipositional cage. The total number of eggs found on the white cotton cloth of treated and untreated ovipositional substrates was recorded four days after release. A cotton pad treated with a 10% sugar solution was provided as adult food.

Acute toxicity of diafenthiuron and profenofos: To assess the toxicity of diafenthiuron, median lethal dose (LD_{50}) to *C. punctiferalis* was determined by topical application and median lethal concentration (LC_{50}) to *S. cardamomi* by capsule dip bioassay. Preliminary range finding tests were made to fix an appropriate dose range. The log-dose/concentration-response curves were fitted. Field collected *C. punctiferalis* larvae were reared on ginger and the larvae weighing 18-22 mg (length 1.2 cm) were used for bioassay. An aliquot of 1 μL of a known dilution of insecticide was placed on the thoracic dorsum of each larva using an 1 μL repeating dispenser (PB 600-01, Hamilton Co. Ltd.) fitted with a 50 μL syringe and a Rheodyne needle. The control was treated with acetone alone.

Thirty larvae per dose were used per treatment. Mortality counts were taken 24 h after treatment. For thrips, capsule dip bioassay method was followed. Uniform size capsules were dipped in different insecticide dilutions for five seconds and then dried on filter paper for 20 min. The capsules were placed in a twelve well plastic tray. The thrips collected from the field using the aspirator were placed on the black cloth. Using a fine zero point camel hairbrush, 20 thrips were transferred on to the treated capsules and the system was covered with a lid. Capsule immersed in water alone served as a control. The test was replicated thrice and the mortality was recorded 48 h after release.

Field evaluation: The field efficacy of neem formulations, diafenthiuron and profenofos and IPM modules against *S. cardamomi* and *C. punctiferalis* were evaluated in the farmer's holding at Lower Pulneys (Dindugul District; Tamil Nadu, India). The bioefficacy experiments (neem, diafenthiuron and profenofos) were laid out in a five year old cardamom plantation using randomized block design. Seven treatments and four replications were used. Each replication covered ten cardamom clumps (cv. Malabar) planted at a spacing of 3×3 m. Spraying was done with a manually operated rocker sprayer. The spray fluid used was one litre/clump. Three sprays were given at an interval of 21 days.

Table 1: Treatment details of IPM modules

Modules	Spray I	Spray II	Spray III	Spray IV	Spray V
M1	N	N	N	D	P
M2	N	N	D	D	P
M3	N	D	D	P	P
M4	N	N	D	P	P
M5	N	D	P	P	P
M6	N	P	D	N	P
M7	N	N	N	N	N
M8	D	D	D	D	D
M9	P	P	P	P	P
M10	Chlorpyrifos	Phosalone	Quinalphos	Dimethoate	Monocrotophos
M 11	Control	Control	Control	Control	Control

N: Neem oil 0.03 EC 1000 mL ha^{-1}, P: Profenofos 50 EC - 500 mL ha^{-1}, D: Diafenthiuron 50 WP - 600 g ai ha^{-1}, Spray interval: 21 days, Control: Water spray

The IPM module experiment was designed based on the pest incidence, effective control, crop stage, honey bee visits and mode of action of insecticides. The experiment was laid out in a randomized block design with eleven treatments and three replications. One hundred cardamom clumps (cultivar Malabar) planted at a spacing of 3×3 m in an eight-year-old plantation constituted one replication. Spraying was done with a manually operated rocker sprayer (high volume sprayer). The spray fluid used was one litre/clump. The treatments were imposed as given in Table 1. Five sprays of TNAU neem 0.03EC, profenofos and diafenthiuron were given at an interval of 21 days and the recommended spray schedule of Spices Board (2001) was kept for comparison (Table 1).

Pest assessment: The *S. cardamomi* damage on cardamom capsules was assessed by counting total number of capsules per five panicles and the infested capsules showing scab symptom and the *C. punctiferalis* damage was assessed based on the infested capsule and shoot showing bore hole symptom. The observations were taken before spraying and 7, 14 and 21 days after each application.

Statistical analysis: The corrected percent reduction in field population was worked out by using the formula of Henderson and Tilton (1955).

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

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

Note: In place of number of insects, per cent damage was substituted.

The per cent damage was subjected to statistical analysis adopting randomized block design. The percentage values were transformed to Arcsine $\sqrt{\text{Percentage}}$. The mean values of treatments were then separated by using Duncan's Multiple Range Test (DMRT) (Gomez and Gomez, 1984).

RESULTS

The deterrent effect of neem on *S. cardamomi* and *C. punctiferalis* has shown that the preference was lowest on NeemAzal 5% treated capsules followed by NeemAzal 1%, TNAU neem 0.03%, Nimbecidine 0.15% and Nimbecidine 0.03% (Table 2). The preference of *C. punctiferalis* for oviposition on neem treated cardamom was lowest in NeemAzal 5% (5.02%) compared to other neem formulations viz., NeemAzal 1% (6.80%), TNAU neem 0.03 EC (9.19%), Nimbecidine 0.15% (11.08%), Nimbecidine 0.03% (14.11%).

The LD_{50} of profenofos, diafenthiuron and endosulfan estimated by topical application to third instar larvae of *C. punctiferalis* was 0.116, 67.932 and 0.254 µg/larva, respectively. Profenofos was found 2.19 times toxic to *C. punctiferalis* than endosulfan (standard check) and also it was more toxic to *S. cardamomi* than diafenthiuron. LC 50 values of diafenthiuron shown that it was more toxic to *S. cardamomi* than dimethoate (standard check) but less toxic than profenofos (Table 3).

The field evaluation of neem formulations and different doses of diafenthiuron and profenofos against *S. cardamomi* and *C. punctiferalis* shown that Neemazal 5%, diafenthiuron 0.16% and profenofos 0.05% were found more effective to control these pests (Table 4-6). Field evaluation of neem formulations showed that, the greatest reduction of *S. cardamomi* and *C. punctiferalis* damages were in Neemazal 5% treated plot followed by TNAU neem (Table 4). The diafenthiuron 0.16% effected greatest reduction of *S. cardamomi* and *C. punctiferalis* damages (Table 5) and the profenofos 0.05% was more effective in controlling *S. cardamomi* and *C. punctiferalis* damages than standard check (monocrotophos 0.072) used for comparison (Table 6).

Table 2: Deterrent effect of neem formulations on *S. cardamomi* and *C. punctiferalis* in cardamom

	Settling preference		Ovipositional preference of *C. punctiferalis*	
Treatments	*S. cardamomi* (%)	*C. punctiferalis* (%)	Number of eggs laid	Eggs laid over control (%)
Nimbecidine 0.03%	12.23 (20.45)^{b}	14.23 (19.03)^{b}	45.33	14.11 (22.05)^{a}
TNAU neem 0.03EC	7.77 (16.15)^{c}	6.77 (17.08)^{c}	29.33	9.19 (17.62)^{c}
Nimbecidine 0.15%	14.43 (22.31)^{b}	12.43 (17.77)^{b}	35.33	11.08 (19.42)^{b}
NeemAzal 1%	4.43 (12.07)^{de}	4.43 (12.39)^{c}	21.70	6.80 (15.07)^{d}
NeemAzal 5%	3.33 (10.40)^{e}	3.33 (11.44)^{c}	16.00	5.02 (12.88)^{e}
Monocrotophos 36 WSC	5.57 (13.40)^{d}	6.57 (9.21)^{d}	28.33	8.88 (17.31)^{c}
Untreated check	52.23 (46.28)^{a}	52.23 (49.26)^{a}	319.00	-

Figures in the parantheses are arc sine $\sqrt{P}$, where P is per cent mortality, Means followed by same letter (s) in a column are not significantly different by DMRT (p = 0.05)

Table 3: Toxicity of diafenthiuron and profenofos against *S. cardamomi* and *C. punctiferalis*

	S. cardamomi			*C. punctiferalis*		
	Diafenthiuron	Profenofos	Dimethoate	Diafenthiuron	Profenofos	Endosulfan
LD_{50} (µg)	23.5	3.2	26.1	67.9	0.1	0.3
95% fiducial limits (UL)	43.1	4.3	39.0	90.9	0.2	0.4
95% fiducial limits (LL)	12.8	2.4	17.4	50.8	0.1	0.2
Y= a + bx	0.7799+0.9655x	1.6793+1.9020x	0.4043+1.2241x	4.0993+1.8831x	1.2238+1.8287x	1.3725+1.5088x
x^2 at P= 0.05	1.562^{NS}	1.002^{NS}	0.203^{NS}	0.589^{NS}	0.658^{NS}	2.190^{NS}
Relative Toxicity	1.1	8.0	1.0	0.1	2.2	1.00

n: No. of larvae used (30) NS: Not significant

Table 4: Field efficacy of neem formulations against *S. cardamomi* and *C. punctiferalis*

		S. cardamomi		*C. punctiferalis*			
				Shoot		Capsule	
Treatments	Conc. (%)	Pre treatment damage (%)	Damage reduction (%)	Pre treatment damage (%)	Damage reduction (%)	Pre treatment damage (%)	Damage reduction (%)
Nimbecidine	0.03	10.4	59.8 (50.6)^{d}	12.1	34.6 (36.0)^{e}	10.5	12.58 (20.75)^{e}
TNAU neem	0.03	10.2	60.4 (50.9)^{c}	11.7	63.0 (52.5)^{b}	9.9	46.70 (43.10)^{c}
Nimbecidine	0.15	9.5	57.1 (49.1)^{e}	11.6	59.4 (50.4)^{d}	10.1	39.81 (39.11)^{d}
NeemAzal	1.0	10.1	56.2 (48.6)^{c}	11.6	60.9 (51.3)^{c}	10.2	43.66 (41.35)^{c}
NeemAzal	5.0	9.4	61.5 (51.6)^{b}	12.2	72.8 (58.6)^{a}	10.6	50.76 (45.40)^{b}
Monocrotophos 36WSC	0.072	9.3	64.5 (53.4)^{a}	12.1	72.9 (58.6)^{a}	10.7	51.74 (45.99)^{a}
Untreated check	-	11.6	-	11.7	-	9.9	-

Figures in the parantheses are arc sine $\sqrt{P}$, where P is percent mortality, Means followed by same letter (s) in a column are not significantly different by DMRT (p = 0.05)

Table 5: Field efficacy of diafenthiuron against *S. cardamomi* and *C. punctiferalis*

		S. cardamomi		*C. punctiferalis*			
				Shoot		Capsule	
Treatments	Conc. (%)	Pre treatment damage (%)	Damage reduction (%)	Pre treatment damage (%)	Damage reduction (%)	Pre treatment damage (%)	Damage reduction (%)
Diafenthiuron 50 WP	0.04	11.3	73.8 (59.2)d	12.6	65.2 (53.8)e	9.3	68.5 (55.9)d
Diafenthiuron 50 WP	0.06	11.3	76.5 (61.1)c	13.1	65.1 (53.8)e	8.9	71.7 (57.9)c
Diafenthiuron 50 WP	0.08	11.9	79.5 (63.1)b	12.9	71.3 (57.6)d	8.4	74.3 (59.5)b
Diafenthiuron 50 WP	0.12	11.5	80.4 (63.8)b	14.4	76.7 (61.2)b	9.5	78.9 (62.7)a
Diafenthiuron 50 WP	0.16	11.6	83.1 (65.7)a	13.2	81.0 (64.2)a	9.6	79.1 (62.8)a
Monocrotophos 36 WSC	0.072	11.6	76.0 (60.7)c	13.5	75.3 (60.2)c	9.2	71.1 (57.5)c
Untreated check	-	12.1	-	12.1	-	9.8	-

Figures in the parantheses arc sine $\sqrt{P}$, where P is percent mortality, Means followed by same letter (s) in a column are not significantly different by DMRT (p = 0.05)

Among the different IPM modules tested, the module containing five sequential sprays of TNAU neem at 0.03%, diafenthiuron 50 WP at 0.06%, profenofos 50 EC at 0.05% and profenofos 50 EC @ 0.05% (M3- NDDPP) was most effective in controlling *S. cardamomi* infestation and the module containing five sequential sprays of neem, profenofos, diafenthiuron, neem and

Table 6: Field efficacy of profenofos against *S. cardamomi* and *C. punctiferalis*

				C. punctiferalis			
		S. cardamomi		Shoot		Capsule	
Treatments	Conc. (%)	Pre treatment damage (%)	Damage reduction (%)	Pre treatment damage (%)	Damage reduction (%)	Pre treatment damage (%)	Damage reduction (%)
Profenofos 50 EC	0.050	15.6	59.7 (50.6)^{c}	11.3	70.7 (57.2)^{d}	8.9	75.9 (60.6)^{d}
Profenofos 50 EC	0.075	15.3	60.3 (50.9)^{c}	11.4	76.8 (61.2)^{c}	9.2	78.7 (61.6)^{c}
Profenofos 50 EC	0.100	14.9	57.0 (49.0)^{d}	11.3	77.3 (61.0)^{c}	9.7	81.5 (64.5)^{b}
Profenofos 50 EC	0.150	15.0	56.2 (48.5)^{d}	11.2	78.3 (62.2)^{b}	8.9	82.4 (65.2)^{ab}
Profenofos 50 EC	0.200	15.2	61.5 (51.6)^{b}	11.6	82.1 (65.1)^{a}	9.1	83.0 (65.6)^{a}
Monocrotophos 36 WSC	0.072	14.7	64.4 (53.4)^{a}	11.5	78.7 (62.5)^{b}	9.2	76.5 (61.0)^{cd}
Untreated check	-	14.9	-	11.1	-	8.7	-

Figures in the parantheses arc sine $\sqrt{P}$, where P is percent mortality, Means followed by same letter (s) in a column are not significantly different by DMRT (p = 0.05)

Table 7: Efficacy and economics of IPM module for control of *S. cardamomi* and *C. punctiferalis*

	Mean % reduction in damages							
			C. Puncitiferalis					
	S. cardamomi		Shoot		Capsule			
Modules	Pre treatment damage (%)	Damage reduction (%)	Pre treatment damage (%)	Damage reduction (%)	Pre treatment damage (%)	Damage reduction (%)	Yield (kg ha^{-1})	Cost benefit ratio
M1-NNNDP	11.4	74.7 (59.8)^{f}	11.2	83.3 (65.9)^{f}	8.8	73.3 (58.9)^{f}	149.5 (12.2)^{f}	01:01.7
M2-NNDDP	11.4	76.3 (60.8)^{e}	11.5	86.1 (68.1)^{d}	8.7	76.8 (61.2)^{e}	152.8 (12.3)^{e}	01:01.9
M3-NDDPP	11.1	91.5 (73.1)^{a}	11.3	86.9 (68.8)^{d}	8.4	78.3 (62.3)^{d}	165.2 (12.8)^{b}	01:02.7
M4-NNDPP	10.3	77 (61.3)^{d}	11.4	85.3 (67.4)^{e}	8.9	80.3 (63.7)^{c}	153.5 (12.4)^{e}	01:01.9
M5-NDPPP	10.6	89.1 (70.7)^{b}	11.5	91 (72.6)^{b}	9	87.1 (68.9)^{b}	155.5 (12.4)^{cd}	01:02.0
M6-NPDNP	10.9	91.3 (72.9)^{a}	11.7	95.3 (77.6)^{a}	9.2	91.4 (72.9)^{a}	168.5 (13.0)^{a}	01:03.0
M7-NNNNN	11.4	59.7 (50.6)^{h}	11.2	55.4 (48.1)^{i}	8.7	57.4 (49.2)^{j}	148.1 (12.1)^{f}	01:01.7
M8-DDDDD	10.7	71.2 (57.5)^{g}	11.8	70.7 (57.2)^{h}	9.1	60.1 (50.8)^{i}	154.1 (12.4)^{de}	01:01.9
M9-PPPPP	11.3	77.2 (61.5)^{d}	11.2	77 (61.4)^{g}	8.9	66.9 (54.8)^{h}	154.6 (12.4)^{de}	01:01.9
M10-Standard	11.3	88 (69.7)^{c}	11.5	89.8 (71.4)^{c}	9.3	71.5 (57.7)^{g}	157 (12.5)^{c}	01:02.0
M11-Control	10.8	74.7 (59.8)^{f}	11.7	-	8.6	73.3 (58.9)^{f}	125.5 (11.2)^{g}	-

Figures in the parantheses are arc sine $\sqrt{P}$, where P is per cent mortality, Means followed by same letter (s) in a column are not significantly different by DMRT (p = 0.05)

profenofos (M 6-NPDNP) was most effective in controlling *C. punctiferalis* infestation. Use of any individual component was less effective in controlling these pests compared to the mixture of components. The module-6 (NPDNP) shown the greatest yield of cured cardamom and cost benefit ratio followed by module-3 (NDDPP) (Table 7).

DISCUSSION

Different IPM modules were tested based on laboratory and field efficacies, the results showed that integrated module M3 (NDDPP) and M6 (NPDNP) were most effective in controlling *S. cardamomi* and *C. punctiferalis* compared to other modules. In both modules the first application

was neem, coincided with flowering and this would have deterred the initial colonization of these pests for oviposition and feeding. These effects were evident from our laboratory studies and this might be due to inhibition on tactile, gustatory and digestive organs of the pests (Mordue *et al.,* 1985).The deterrent effects depends on azadirachtin content of the neem formulations, if the azadirachtin content is more, the deterrent effect would also be greater and persist for longer time in the plant. The present study confirms the earlier reports of effects of neem on several crop pests (Meisner *et al.*, 1992; Rembold and Sieber, 1981).

Further spray of insecticides with different mode of action, chemistry and persistence would make the module more effective in controlling the pests. Diafenthiuron is a new insecticide having novel mode of action and its bioefficacy was confirmed by laboratory and field experiments. This is in consistent with previous reports on sap feeders like *B. tabaci* on cotton (Chinnabbai *et al.*, 2000; Cai, 1998) *S. dorsalis* on hot pepper (Vos *et al.*, 1991).

Profenofos is also an alternative to conventional insecticides used in cardamom, found effective in controlling of *S. cardamomi* and *C. punctiferalis*, less persistent in cured cardamom (Renuka *et al.*, 2006) and the effectiveness was confirmed by laboratory and field tests. Among the different concentrations used, profenofos at 0.05% was cost effective and it is in consistent with previous reports on other pests (Omar and Haydar, 1988; Srinivas and Clement Peter, 1993; Muthukrishnan *et al.*, 1994; Saradha and Nachiappan, 2003; Zuhua and Shusheng, 1998; Cheng *et al.*, 1999). Although, the dose is important in efficacy, considering the cost effectiveness, diafenthiuron at 0.06 per cent could be used for the management of these pests.

Other neem based modules (M1, M2, M4, M8) shown greater reduction in *S. cardamomi* and *C. punctiferalis* infestations compared to untreated check (M11) but the efficacy and yield were decreased with frequency of neem application (Table 7). This might be due to increasing the frequency of neem application would make the insects to adapt for azadirachtin compounds and to develop resistance (Feng and Ishman, 1995). Furthermore, the persistence of neem in field condition is less when compared to laboratory condition and the azadirachtin compound get photo degraded under UV light (Carboni *et al.*, 2002; Capinera and Froeba, 2007) hence, this wide spray interval (21 days) might not be sufficient for complete protection of crops from the pests that were not covered by neem or exposed at sub lethal concentration. Hence, subsequent management needs a chemical control with a novel mode of action.

The standard check (M 10), sequential application of broad spectrum insecticides was less effective in control of *S. cardamomi* and *C. punctiferalis* compared to the integrated modules (M3&M6) and the cost benefit ratio was also found lower than integrated modules. Sequential application of same group of insecticides having single target site for action would lead resistance (Feng and Ishman, 1995) and this might be the reason for decreasing effect on pests control and a reduction in the yield.

Though, the Neemazal 5% is most effective against these pests, found expensive and use of TNAU neem was cost effective. Its effectiveness was evident from greatest benefit cost in M6. However, other neem formulations could be substituted for TNAU neem, based on market value of the produce. At present no alternative to chemical control against the cardamom pests and the planters completely depends on conventional insecticides. This IPM modules would reduce the number of conventional spray with broad spectrum insecticide and effective against these pests. Even though alternative methods like *Bacillus thuringiensis* (Devasahayam, 2000), entomopathogenic nemetodes (Choo *et al.*, 2001) and sex pheromones (Rajabaskar and Regupathy, 2012) were reported for management of *C. punctiferalis*, these could be further explored and included in the IPM programme for long term sustainability of cardamom plantation.

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