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Management of sapota bud borer - *Anarsia achrasella* Bradley (Lepidoptera: Tortricidae) with attractants and insecticides

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Abstract
In sapota, to manage the bud borer - *Anarsia achrasella* Bradley experiments were carried out with an objective that monitoring the peak incidence, to found out an effective food bait for adult moth attraction and to test the efficacy of different insecticides including bio-agents and botanicals. Monitoring study revealed that bud borer incidence was started during I Fortnight (FN) of September and reached upto 6.88% during November II FN. During July to August there was no BB damage. Two peaks one on November II FN (6.88%) and the second on January I FN (5.62%) were observed. Moth catches showed significant positive correlation with relative humidity. In the food bait technology to attract the adult moths, black tulsi extract baited traps (152.50 adults / traps / week) followed by Acetic Acid with Methyl I Butanol (AAMB) baited traps (126 adults / traps / week) caught more number of BB moths. Also the BB damage in black tulsi extract, floral lure and AAMB ranged from 9.84 to 10.54% as against 22.92% in control. Hence, either BTE or AAMB may be a useful tool for monitoring bud borer moths in sapota orchard, to determine their presence, and potentially to assess the risk of damaging infestations. In the bio-efficacy experiment, *Bacillus thuringiensis* 5 WP – 0.0075% found to be superior to other treatments and which was followed by profenophos (0.075%) and Emamectin benzoate 0.4ml / lit in terms of overall BB damage (7.87,10.36 and10.80%) marketable fruit yield (13.98,12.23 and 12.85 t/ha) and economic returns (1:10.6;1:8.2 and1:8.0).

Keywords: Bud borer, black tulsi extract, Acetic Acid with Methyl I Butanol, mass trapping, *Bacillus thuringiensis*, Emamectin benzoate

Introduction
Sapota or sapodilla (*Manilkara achras*) is an important sweet fruit of tropical region. India is considered to be the largest producer of sapota in the world with an area of about 1.60 lakh hectares and production of 1424 metric tones (Sathish *et al*., 2014) [1]. It has attained the status of major fruit crop in Gujarat, Andhra Pradesh, Karnataka, Maharastra and Tamil Nadu (Anonymus, 2014) [2]. It is largely grown in Gujarat, Maharashtra, Karnataka, Tamil Nadu, Kerala, Uttarapradesh, Haryana, Punjab and West Bengal (Vijayaraghavendra and Basavanagoud, 2017) [3]. However, continuous flowering and fruiting pattern of sapota changing ecological conditions favours the proliferation of insect pests in sapota. Among the various factors affecting the yield and quality of fruit crops, the damage caused by insect pests is considered as a major constraint. Sapota tree is attacked by more than 25 insect pests which include bud borer, chiku moth, midrib folder, leaf miner, fruit flies and sucking pests (Butani 1979 and Shukla, 2011) [4-5]. Among these, sapota/chiku bud borer *Anarsia achrasella* Bradley (Lepidoptera: Tortricidae) is one of the major and regular pests causing damage to the sapota crop starting from flowering to till harvest. Hence this pest is active throughout the year. Jhala *et al* (1968) [6] recorded the bud borer damage ranged from 2.0 to 15.0% on flower buds. Indiscriminate use of chemicals to control insect pest not only causes the economical restrain on farmers but also produces the 3R (Resistance, Resurgence and Residue) problem in an environment and human being. Hence, use of plant products and bio-agents may help to reduce the insect pest problem ultimately the 3R problems. Besides, the knowledge on the occurrence and its peak activity of the pest also paves the best way to manage the insect pest on correct time. With the importance of bud borer damage intensity and necessity of management technology, in the present study, evaluation of certain bait materials including

botanicals to lure adults of bud borer and evaluation of certain botanicals, microbials and insecticides were tested under field condition to minimize bud borer damage and the yield loss. In light of this, the trial was conducted with an objective to develop new lure for mass trapping of sapota bud borer and to test the bio-efficacy of insecticides including botanicals and bio-agents for managing bud borer in sapota.

Materials and Methods

Two experiments, one on mass trapping of bud borer adult moths with botanicals and the second experiment on testing the bio-efficacy of different insecticides including botanicals against sapota bud borer were carried out in sapota orchard at Horticultural College and Research Institute farm (10.1239ºN, 77.5475º E), Tamil Nadu Agricultural University, Periyakulam, Theni district, Tamil Nadu during 2021 - 2022**.** More than 15 years old Sapota variety PKM 1 planted in 10 × 10 m spacing was chosen for the experiments. Weather parameters and the bud borer incidence were recorded starting from January I Fortnight (FN) to December II FN during 2021-2022.

Sapota bud borer adult mass trapping with plant products

The traps used to attract bud borer was the same type as that of fruit fly trap. The traps with different attractants used for mass trapping the bud borer adults were 1. Black tulsi extract lure 1: 2 Mixture (tulsi and water), 2. Black tulsi extract lure 1: 1 Mixture (tulsi and water), 3. AAMB lure (Acetic Acid with Methyl I Butanol) (50: 50 mixture), 4. Floral lure (Mixture of Phenyl acetaldehyde: Methyl salicylate: Methylmethoxy benzoate. Equal proportion), 5. Fermented sapota fruits 1: 2 Mixture (sapota and water), 6. Fermented pineapple fruits 1:2 Mixture (pineapple fruits and water), 7. Omam oil 1:2 Mixture (Omam oil and water), 8. Geranium oil 1: 2 Mixture (Geranium oil and water), 9. Lemon grass oil 1:2 Mixture (lemon grass oil and water) and 10. Control. Black tulsi trap was prepared by using its extract. To prepare the extract, 500 g leaves of black tulsi was taken in one liter of water and grounded thoroughly by the electrical blender and the extract was filtered through muslin cloth. To this extract, after adding 2 ml of DDVP a piece of sponge or cotton swab was soaked in the solution and kept in the trap. Such traps were installed in the orchard @ 1 trap / 20 trees at 3 -5 mt above ground level on the branch remaining outside the tree canopy. The attractions of moths were recorded at weekly interval for six months starting from flowering to complete harvest of fruits. The baits were replaced once in a fortnight.

Bio-efficacy of insecticides including bio-agents against sapota bud borer

The bio-efficacy experiment was conducted with eight different treatments including insecticides, bio-control agents and control. The eight treatments *viz*., T_1 spinosad 45 SC – 0.0169%, T_2 profenophos (0.075%), T_3 novaluron 10 EC - 1 ml / 1it, T_4 emamectin benzoate 0.4 ml / lit, T_5 *Metarhizium* @ 1 x 10^6 / ml, T_6 *B.t.* spray 5 WP - 0.0075%, T_7 Azadirachtin 1000 ppm – 3 ml /1it and T_8 control were replicated thrice in a randomized block design (RBD). Each treatment was given to all the trees in a single line and the observations were taken from selected three trees considering one tree as one replication. The insecticide treatments were imposed at the time of initiation of bud borer incidence. Totally two sprays were imposed at an interval of 20 days. Observations on the bud borer incidence as pre-treatment count and 5th, 10th and 14th day after treatment were recorded. The percentage of bud borer incidence was calculated by the total number of buds observed and the number of buds damaged by bud borer counted from each twig. All the necessary recommended packages of practices were followed during the sapota cropping season.

Statistical Analysis

Observations on bud borer damage (%), damaged fruit yield, marketable fruit yield per tree recorded were analysed using OPSTAT (Sheoran *et al*., 1998) [7]. The cost benefit ratio for each treatment was worked out.

Results and Discussion

Correlation of weather parameters with bud borer incidence (%) in sapota

Onset of bud borer incidence was started during I Fortnight (FN) of September and it gradually reached upto 6.88% during November II FN (Table 1). Thereafter it gradually declined to 0.65 during June II FN. During July to August there was no bud borer damage. Two peaks were observed for the year 2021-2022 (Table 1). First one on November II FN (6.88%) and the second peak on January I FN (5.62%). Ghirtlahre *et al*., (2016) [8] reported the highest bud borer incidence of 47.5% during the I week of November in plain. They observed the minimum damage of 9.75% during I week of August. In contrast, our studies showed that during July to August there was nil incidence of bud borer in sapota. There was a negative correlation with maximum and minimum temperatures, morning and evening relative humidity, and sunshine hours, while rainfall was found favourable for pest population in the field (Ghirtlahre *et al*., 2016)[8]. In the present investigation, it was noticed that there was a significant positive correlation between the relative humidity and bud borer incidence. All the other weather parameters showed a negative non-significant influence on bud borer incidence. In another study, which was conducted in hilly region of Karnataka showed that, there was a significant and positive correlation between bud borer damage and maximum temperature. Rest of the weather factors *viz*., minimum temperature, relative humidity and rain fall had no influence on pest population during the period of study (Sathish *et al*., 2014). It could be inferred that, by using one year data on weather parameters and bud borer incidence has given an idea about the peak incidence of bud borer in sapota.

Effect of attractants in sapota bud borer catches, incidence and yield

The mean weekly trap catches of bud borer to various attractants revealed that mixture of black tulsi extract lure attracted more bud borer moths (152.50 adults/traps/week). In mango orchard, among the different bait materials kept for fruit fly attraction, combination of black tulsi (leaf extract) + Malathion and black tulsi (leaf extract) + Spinosad combination was found to be an effective attractants than other baits (Parab *et al*., 2018a) [9]. Parab *et al*., (2018b) [10] reported that black tulsi (leaf extract) + malathion and black tulsi (leaf extract) + spinosad attracted maximum number of fruit flies (190/month/trap) and (190/month/trap). Mixture of black tulsi extract lure 1:1 (Tulsi and water) recorded minimum bud borer damage (9.84%) after 6 months of treatment. This treatment was on a par with AAMB lure (Acetic Acid and Methyl-I-Butanol) mixture (10.54%) and floral lure (10.29%). Results of the present study are in line

with the findings of Londolt *et al*., (2011) [11]. Londolt *et al*., (2011) [11] reported that hop looper moths, *Hypena humuli* Harris (Lepidoptera: Erebidae) in hap yards were captured in traps baited with a combination of acetic acid plus 3-methyl-1-butanol (AAMB). They also reported that the two chemicals were synergistic in attracting hop looper moths. In a comparison of the lure chemicals, most moths were trapped with AAMB as the lure, while very few moths were captured in traps baited with acetic acid alone or 3-methyl-1-butanol alone (Londolt *et al*., 2011). AAMB is attractive to a number of species of noctuid, pyralid, erebid, and other moths (Landolt and Alfaro 2001; Landolt and Hammond 2001; Landolt and Higbee 2002; Toth *et al*., 2002, 2010; Landolt *et al*. 2006) [12-17]. Result of the present investigation showed that the AAMB attracts the Tortricidae moth *Anarsia achrasella* Bradley.

The sapota bud borer incidence (%) reduction over control after 6 months of treatment was highest (57.00%) in mixture of black Tulsi extract lure with water 1:1. Similary, the same treatment recorded minimum of 5.19 larvae/50 twigs, which was statistically significant from other treatments. The marketable fruit yield was also maximum in the same treatment (16.93t / ha) followed by fermented sapota fruits lure which recorded 16.17 t/ha (Table 2). Traps are often used to determine the occurrence of insect pests in cropping ecosystem, and in some cases to indicate the need for, or timing, of pest control measures. Sex pheromones are used as attractants for trapping numerous species of pest moths but an attractive sex pheromone has not been identified for the sapota bud borer. Botanical attractant (Black tulsi extract) in a trap attracted more bud borer moth, which could provide a low input and inexpensive means for monitoring bud borer in sapota orchards, and so potentially improve pest management. Since the effect of black tulsi extract and AAMB are on par with each other black tulsi may be recommended based on its botanical in nature and eco-friendly and more marketable fruit yield recorded. Besides, black tulsi can be used as baiting material for trapping bud borer in sapota orchard due to its availability at farmer's field, cheaper and effective and can be replaced in the absence of AAMB.

Bio-efficacy of insecticides and bio-agents in sapota bud borer management

In the bio-efficacy trial, it was evident that the effect of *B. t* against sapota bud borer was superior to other treatments. *B. t* treated sapota trees recorded less incidence of bud borer on 10 DAS (7.85%) and 20 DAS (8.48%) after the first spray and the same trend was observed on 10DAS (6.82%) and on 20DAS (8.36%) after the second spray. As a result of reduced damage, the same treatment recorded more CBR of 1:10.6. Results of the present study was in line with the findings of Suryavanshi and Patel (2009)[18], who reported that the effect of *B.t* on sapota bud borer reduction was on par with the chemical insecticides Polytrin-C (combination of profenophos and cypermethrin) @ 0.044 per cent (0.69%) and Nurelle-D @ 0.055 per cent (1.40%) effect. In the present study also, next to *B.t* more BCR of 1:8.2 and 1:8.0 was recorded in profenophos and emamectin benzoate (Table 3). This might be due the effect of profenophos in reducing the incidence of bud borer in sapota on 10 DAS and 20 DAS (8.46 and 11.62%) after first spray and second spray (9.66% and 11.66%). This treatment was followed by emamectin benzoate, which recorded bud borer damage of 9.51% and 11.83% on 10 DAS and 20 DAS after first spray and 9.68% and 12.22% on 10 DAS and 20 DAS after second spray. The overall per cent bud damage data also revealed that all the insecticidal treatments, bio-agents and botanicals were significantly superior to control in suppressing the bud borer damage. Based on the effect of *B.t* on bud borer incidence and economic returns it may be recommended for managing the sapota bud borer. Since it's a bio-agent it would serve as an environmentally benign insecticide in sapota ecosystem.

Conclusion

In could be inferred that two peak catches of bud borer was noticed and the bud borer catches showed significant positive correlation with relative humidity. The plant products blacl tulsi extract attracted more number of bud borer adults and the *B.t* showed superior to other treatments in controlling bud borer damage. Hence, the plant product and bio-agent would serve as a best component of an effective IPM for the bud borer management in sapota ecosystem.

Table 1: Correlation of weather parameters with bud borer incidence (%) in sapota

Month	Temperature ºC		Rainfall (mm)	RH (%)	Bud borer damage (%)
	Maximum	Minimum			
JAN I	23.86	22.72	0.00	64.10	5.62
JAN II	22.54	21.44	0.00	71.66	5.26
FEB I	24.57	23.31	0.00	66.57	4.24
FEB II	24.46	23.06	0.00	65.07	4.00
MAR I	26.79	24.69	1.60	67.10	3.00
MAR II	28.10	27.18	9.33	55.34	2.66
APRL I	28.37	26.19	32.20	57.67	2.42
APRL II	29.35	27.73	6.20	58.13	1.80
MAY I	28.97	27.33	42.60	60.87	1.64
MAY II	29.24	27.66	10.12	65.03	1.70
JUN I	28.73	27.17	28.60	61.57	1.00
JUN II	28.60	26.97	1.40	60.60	0.65
JUL I	27.43	25.67	43.80	68.57	0.00
JUL II	27.24	25.58	3.08	67.31	0.00
AUG I	26.99	25.23	24.00	73.30	0.00
AUG II	27.44	25.82	9.70	63.00	0.00
SEP I	25.84	24.13	30.20	77.37	1.21
SEP II	26.41	24.79	34.33	72.33	1.58
OCT I	27.31	25.60	20.60	64.30	3.00
OCT II	26.93	24.59	4.30	68.28	3.82

NOV I	25.40	23.51	68.80	74.90	4.62
NOV II	24.60	22.61	38.76	77.53	6.88
DEC I	24.16	22.18	8.00	79.53	6.42
DEC II	23.16	21.23	5.84	75.66	6.00
Correlation	-0.76	-0.77	-0.13	0.42	-

Table 1a: Correlation Matrix of effect of weather parameters on population of sapota seed borer

	R	**-0.75862**	**-0.77127**	**-0.12523**	**0.42402**	**-0.03238**
	Y = a + bx	**-0.820X = 24.583**	**-0.840X = 23.694**	**-0.01X = 3.072**	**0.136 X – 6.363**	**-0.149X = 3.293**
Bud borer Population	Significance (P value)	-	-	-	0.039	-
	Non-Significance (P value)	<0.01	<0.01	0.561	-	0.881

Table 2: Effect of plant products extract in bud borer trap catches, incidence and yield of sapota

SN	Treatments	Bud borer Damage (%)		PROC (%)	Larval population/50 twigs	Damaged fruit yield (t/ha)	Marketable Fruit yield (t/ha)	Mean Trap catches/ week/ trap/
		Pre-treatment	Post-treatment					
T_1	Black tulsiextract lure 1:2 (Tulsi and water)	17.38 (24.63)	10.80[b] (19.08)	52.80	7.40 [c] (2.89)	1.017	15.047	76.00
T_2	Black tulsi extract lure 1:1 (Tulsi and water)	17.12 (24.42)	9.84[a] (18.22)	57.00	5.19[a] (2.48)	0.983	16.93	152.50
T_3	AAMB lure (Acetic acid with Methyl I Butanol) (50:50 mixture)	17.37 (24.60)	10.54[a] (18.87)	54.00	5.95[b] (2.63)	0.85	11.65	126.00
T_4	Floral lure (Equal portion of Phenyl acetaldehyde, Methyl Salicylate, Methylmethoxy benzoate)	20.11 (26.61)	10.29[a] (18.65)	55.10	5.62[a] (2.56)	1.05	14.33	118.50
T_5	Fermented sapota fruits 1:2 Mixture (sapota and water)	19.58 (26.24)	12.27[b] (20.45)	46.46	5.82[b] (2.61)	0.92	16.17	138.75
T_6	Fermented pineapple fruits 1:2 Mixture (pineapple fruits and water)	19.65 (26.30)	13.80[c] (21.75)	39.79	7.17[c] (2.85)	1.27	13.30	102.00
T_7	Omam oil 1:2 Mixture (Omam oil and water)	21.45 27.54)	16.04[c] (23.57)	33.00	6.89[c] (2.81)	1.08	12.15	82.50
T_8	Geranium oil 1:2 Mixture (Geranium oil and water)	21.80 (27.79)	17.05[d] (24.35)	25.61	7.33[c] (2.88)	1.04	11.02	102.75
T_9	Lemon grass oil 1:2 Mixture (lemon grass oil and water)	20.13 (26.63)	16.14[c] (23.65)	29.15	7.12[c] (2.84)	1.07	10.21	115.00
T_{10}	Control	19.86 (26.45)	22.92[e] (28.59)	-	13.99[d] (3.87)	1.56	6.53	3.00
	C.D.	2.017	1.388	-	0.12	0.37	0.97	-
	SE(m)	0.67	0.464	-	0.04	0.12	0.32	-
	SE(d)	0.95	0.656	-	0.06	0.17	0.46	-
	C.V.	4.46	3.696	-	2.61	19.82	4.43	-

Figures in the paranthesis are arc sine transformed values.

Table 3: Effect of insecticides and bio-agents on bug borer incidence in sapota

SN	Treatments	Bud bored Damage (%)			Mean	Bud bored Damage (%)		Mean	Over all Bud damage (%)	Yield (t/ha)	BCR
		PTC	First spray			Second spray					
			10DAS	20 DAS		10 DAS	20 DAS				
T_1	Spinosad 45 SC – 0.0169%	24.92 (29.74)	12.74 (20.18)	12.22 (19.67)	12.48 (19.92)	10.42 (17.72)	12.14 (19.59)	11.28 (18.66)	11.88	12.42	1:7:6
T_2	Profenophos (0.075%)	24.28 (29.30)	9.51 (16.58)	11.83 (19.27)	10.67 (17.93)	8.46 (14.90)	11.62 (19.05)	10.04 (16.98)	10.36	12.23	1:8:2
T_3	Novoluron 10 EC – 1 ml /1it	23.85 (29.01)	13.65 (21.05)	15.54 (22.72)	14.59 (21.89)	14.82 (22.09)	16.68 (23.66)	15.75 (22.88)	15.17	9.52	1:5:2
T_4	Emamectinbenzoate 0.4ml / lit	24.55 (29.48)	9.68 (16.81)	12.22 (19.67)	10.95 (18.24)	9.66 (16.78)	11.66 (19.09)	10.66 (17.94)	10.80	12.85	1:8:0
T_5	*Metarhizium* @ 1 x 10^6/ml	23.92 (29.05)	15.88 (23.00)	16.64 (23.63)	16.26 (23.32)	15.32 (22.53)	16.88 (23.83)	16.10 (23.18)	16.18	8.86	1:4:6
T_6	*B.t.* 5 WP – (0.0075%)	24.55 (29.48)	7.85 (16.18)	8.48 (16.85)	8.16 (16.52)	6.82 (17.31)	8.36 (14.69)	8.79 (16.00)	7.87	13.98	1:10:6
T_7	Azadirachtin 1000 ppm – 3 ml/1	22.26 (27.89)	13.64 (21.04)	11.82 (19.26)	12.73 (20.15)	12.32 (19.77)	11.24 (18.65)	11.78 (19.21)	12.25	9.66	1:5:6
T_8	Control	25.02 (29.68)	26.32 (30.35)	27.68 (31.57)	27.00 (30.96)	29.43 (32.70)	29.78 (32.93)	29.61 (32.82)	28.40	8.54	-
	C.D.	0.83	3.90	3.37	-	3.85	2.82	-	-	0.62	-
	SE(m)	0.27	1.27	1.10	-	1.26	0.92	-	-	0.20	-
	SE(d)	0.38	1.80	1.56	-	1.78	1.30	-	-	0.28	-
	C.V.	1.60	10.68	8.85	-	10.64	7.44	-	-	3.21	-

Figures in the paranthesis are arc sin transformed values. Values are mean of three replications for each treatment

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