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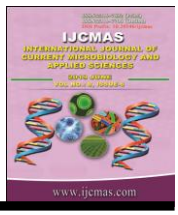

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Management of Coffee White Stem Borer *Xylotrechus quadripes* (Chevrolat, 1863) (Coleoptera: Cerambycidae) in the Lower Pulney Hills, India

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A B S T R A C T

The bio-efficacy of bio-agents *viz.*, *Beauveria bassiana* 2% A.S. @ 10ml/lit, *Bacillus subtilis* @ 10/lit and azadirachtin 1% EC @ 1ml/lit and chemical insecticide *viz.*, chlorpyriphos 20 EC @ 3ml/lit, chlorantraniliprole 20 SC @ 0.5ml/lit and fipronil 40% + imidacloprid 40% WG @ 0.5g/lit were assessed against coffee white stem borer *Xylotrechus quadripes* (Chevrolat, 1863) (Cerambycidae: Coleoptera) in lower Pulney hills, Tamil Nadu. Coinciding with the adult emergence, three sprays were given: I spray (first week of April, 2018), II spray (first week of October, 2018) and III spray (last week of October, 2018) in two field trials, compared with untreated control. In both field trials the maximum control was observed in chlorpyriphos 20 EC + azadirachtin 1% EC @ 3ml + 1ml (45.56 % and 36.67 %) followed by chlorpyriphos 20 EC @ 3ml/lit (45.56% and 37.72%), *Beauveria bassiana* 2% A.S. @ 10ml/lit (48.89% and 43.33%) and chlorantraniliprole 20 SC @ 0.5ml/lit (51.67% and 46.11%) as against control (84.44% and 80.56%).

Introduction

Coffee (*Coffea arabica*) the most important perennial beverage plant is believed to have been introduced into India in the Chikmagalur hills in 1600 AD by a Muslim pilgrim, Bababudan from Yemen (Central Coffee Research Institute (CCRI, 2003). In the late 1820's coffee plantations were established in South India by the British. At present in India, coffee (*arabica* and *robusta*) cultivation is mainly confined to the states of Karnataka (53.8%), Kerala (18.9%), Tamil Nadu (7.8%) and other parts of North Eastern India (1.8%). The global coffee bean production is surplus against consumption accounting to 99.11 lakh tonnes/ year with 3.38 per cent share from India. The productivity of coffee in India is 765kg/ha. In Tamil Nadu, coffee is mainly produced in the Nilgiris, Shevroy hills,

Pulney hills and Anamalai hills in 13,436 ha. The average production of Tamil Nadu is 17,440 tonnes/year and productivity of 519kg/ha (CCRI, 2018).

Despite the surplus production, insects are a major constraint in achieving higher yields. More than 100 insects have been recorded as pests in coffee (Le Pelley, 1968). Of these insect pests, coffee white stem borer (CWSB) *Xylotrechus quadripes* (Chevrolat, 1863) (Cerambycidae: Coleoptera) was observed to devastate the coffee bushes, sometimes, accounting to a crop loss of $26-40 million (Hall *et al.,* 2006; Venkatasha, 2010) elsewhere. The annual economic loss in India due to CWSB accounts to 0.64 million US dollars in 1987 and 1997 (Radhakrishnan *et al.,* 1987; Naidu, 1997), 40 million US dollars in 2006 (Hall *et al.,* 2006) and 26 million in 2010 (Venkatesha, 2010).

CWSB is considered to be a native of South East Asia had been recorded from China (Kuang *et al.,* 1977), Sri Lanka, Thailand, Vietnam, Java and Burma (Le Pelley, 1968) and India (Stokes, 1838). In India, it is distributed over the *arabica* coffee tracts of Karnataka, Tamil Nadu, Kerala and Andhra Pradesh. The coffee productivity deficit of 246kg in Tamil Nadu is mainly attributed to loss by insect damage. In the study area, Pulney hills, *arabica* coffee is widely grown in 13,436ha, where in CWSB is a recent menace. The adult emergence of the CWSB occurs during pre-monsoon period (April to May) post-monsoon period (October to November). The present study was undertaken to evaluate the bio-efficacy of bio-agents *viz., Beauveria bassiana, Bacillus subtilis* and azadirachtin against CWSB in comparison with chemical insecticides so as to develop alternative methods of management, keeping in view of the health and environmental hazards by pesticide usage.

Materials and Methods

Two field experiments for the damage assessment based management of CWSB (Trial I and Trial II) were conducted from January, 2018 to January, 2019 at Kodai Nursery Estate, Thadiyankudisai, Dindigul, Tamil Nadu, (77.71˚ E, 10.29˚ N) India. The efficacy of bio-agents *Beauveria bassiana, Bacillus subtilis*, azadirachtin and chemical insecticides *viz.*, chlorpyriphos, chlorantraniliprole and fipronil 40% + imidacloprid 40% WG were evaluated at the dosages presented in Table 1. The experiments were laid out in randomized block design and replicated three times. Each replication comprised 20 year old *arabica* coffee plants 10 in numbers. The treatments were imposed three times: I spray (first week of April, 2018), II spray (first week of October, 2018) and III spray (last week of October, 2018) coinciding with the adult emergence.

CWSB larvae damaged the coffee stem by making galleries that appeared like ridges made in a circular manner around the main stem and primary branches. Subsequently, the larvae tunneled into the stem feeding from within. Sometimes they bored down to the root resulting in yellowing of leaves and wilting of the plants.

The damage by CWSB was recorded by observing the ridge formation on the main stem and thick primary branches (Fig. 1).

The pre-treatment spray count on damage by CWSB was recorded one day before spray and the post treatment count was recorded on 10, 20, 30, 40, 50 and 60 days after spray (DAS) for the I and III spray only, the post treatment count was limited to 10 and 20 DAS for the second spray so as to impose the II round of treatment during the first week of October, 2018.

The coffee yield in different treatments was quantified separately in terms of kg per 30 plants.

The data recorded were transformed in to arc sin values for statistical scrutiny, the following method, WASP-Web Agri Stat Package (http://www.ccari.res.in/wasp/rbd2.php).

Results and Discussion

Field experiment of chemical and bio-agent against CWSB

Effect of bio-agents against CWSB in the I trial

The results on efficacy of different chemicals and bio-agents revealed that there was significant difference between treatments in all three applications on the infestation level of the CWSB (Table 2). After first application the minimum infestation was recorded in chlorpyriphos 20 EC + azadirachtin 1% EC & chlorpyriphos 20 EC (40.56%) followed by *Beauveria bassiana* 2% A.S. (41.11%) sprayed plots and were on par with each other statistically. In the untreated control plots the infestation was maximum (52.22%). Similar trend was noticed in second and third application also. However, during second and third treatment application the level of infestation was more. During third treatment spraying the untreated plots had maximum damage of 84.44 per cent by CWSB.

The infestation level was minimum in chlorpyriphos 20 EC + azadirachtin 1% EC & chlorpyriphos 20 EC (45.56%) applied plots. There was significant impact for the bio-agent *Beauveria bassiana* 2% A.S and *Bacillus subtilis* 1.5 % WS on the damage by CWSB. The level of infestation after third application in these treatments was 48.89 and 55.56 per cent respectively.

The field studies on the efficacy of bio-agents against CWSB in the II trial

Among the three applications in all the treatments, the influence of synthetic insecticide sprays on CWSB damage has been realized (Table 3). The minimum damaged control ranged from 34.22 per cent (chlorpyriphos 20 EC + azadirachtin 1% EC) and 34.91 per cent (chlorpyriphos 20 EC) followed by 35.59 per cent (*Beauveria bassiana* 2% A.S) and was significantly equal in treatment plots after the first application. The maximum incidence of CWSB was 51.11 per cent in untreated control plots. In these treatments, the second application also observed the same percentage of infestation, the maximum infestation was observed in untreated control plots (61.67 %) in second application.

The minimum per cent infestation (38-33) was observed in plots treated with insecticides (chlorpyriphos 20 EC + azadirachtin 1% EC and chlorpyriphos 20 EC) and were significantly on par with each other, followed by the bio-agent of *Beauveria bassiana* 2% A.S. with 43.33 per cent in third application. In all the three application the maximum stem borer damage was observed in untreated control plots 80.56%.

Effect of bio-agents against CWSB on yield of coffee

Coffee yield varied with treatments (Table 4). The coffee grown in the control plots (untreated) had the lowest yield compared to chemical treatments (22.68 and 22.40 kg/30 plants), respectively in the trial I and II. The insecticide treated plots with chlorpyriphos 20 EC + azadirachtin 1% EC had the highest yield, (52.58 and 51.32kg/30plants), followed by chlorpyriphos 20EC (51.86 and 50.86kg/30plants) and *Beauveria bassiana* 2% A.S. (47.47 and 46.94kg/plants).

Table.1 Experiment treatments for the management of CWSB

Treatments	Quantity/litre of water	Types of sprayer	Types of Nozzle	Application methods	Formulated product manufacturer
T_1 - Fipronil 40% + Imidacloprid 40%WG	0.5g	Knapsack (15lit capacity)	Hollow cone nozzle (1000 litre of spray fluid per hectare)	Spraying	Bayer Crop Science Limited, India
T_2 - Chlorantraniliprole 20 SC	0.5ml				DuPont India Private Limited
T_3 - Chlorpyrifos 20 EC	3ml				Dow Agro Sciences India Pvt. Ltd.
T_4 - Azadirachtin 1% EC	1ml				E.I.D. Parry (India) Limited
T_5 - (Fipronil 40 %+ Imidacloprid 40%WG) + Azadirachtin 1% EC	0.5g + 1ml				Chemicals mixed before spraying
T_6 - Chlorantraniliprole 20 SC + Azadirachtin 1% EC	0.5ml + 1ml				
T_7 - Chlorpyrifos 20 EC + Azadirachtin 1% EC	3ml + 1ml				
T_8 - *Bacillus subtilis* 1.5% WS	10ml				TNAU Culture
T_9 - *Beauveria bassiana* 2% A.S.	10ml				International Panaacea Limited, India
T_{10} - Untreated control	-				-

Table.2 Field evaluation of bio-agents against coffee white stem borer (Trial I)

Treatments	Dose/lit of water	PTC	Percent infestation after		
			1st Application	2nd Application	3rd Application
T_1 - Fipronil 40% + Imidacloprid 40%WG	0.5g	36.67	46.11 (42.75)d	58.33 (49.80)ef	65.56 (54.11)f
T_2 - Chlorantraniliprole 20 SC	0.5ml	40.00	42.78 (40.84)abc	50.00 (45.00)bcd	55.00 (47.87)cd
T_3 - Chlorpyrifos 20 EC	3ml	40.00	40.56 (39.55)a	43.33 (41.16)a	45.56 (42.44)a
T_4 - Azadirachtin 1% EC	1ml	36.67	44.44 (41.79)cd	53.33 (46.91)cd	60.56 (51.11)d
T_5 - (Fipronil 40% + Imidacloprid 40%WG) + Azadirachtin 1% EC	0.5g + 1ml	40.00	45.00 (42.12)cd	55.00 (47.88)cd	63.33 (52.75)ef
T_6 - Chlorantraniliprole 20 SC + Azadirachtin 1% EC	0.5ml + 1ml	40.00	41.67 (40.17)ab	46.67 (43.08)abc	51.67 (45.95)bc
T_7 - Chlorpyrifos 20 EC + Azadirachtin 1% EC	3ml + 1ml	40.00	40.56 (39.55)a	43.33 (41.16)a	45.56 (41.02)a
T_8 - *Bacillus subtilis* 1.5% WS	10ml	36.67	43.33 (41.15)bc	51.67 (45.95)cd	55.56 (48.19)d
T_9 - *Beauveria bassiana* 2% A.S.	10ml	40.00	41.11 (39.87)ab	45.00 (42.12)ab	48.89 (44.36)ab
T_{10} - Untreated control	-	43.33	52.22 (46.27)e	63.33 (52.75)f	84.44 (67.35)g
CV %		26.39	2.99	2.89	3.65
CD (0.05%)		NS	1.44	2.98	2.10
SEm±		8.47	1.53	1.73	3.27

PTC – Pre Treatment Count

Figures in parentheses are arc sin transformed values

Table.3 Field evaluation of bio-agents against coffee white stem borer (Trial II)

Treatments	Dose/litre of water	PTC	Percent infestation after		
			1st Application	2nd Application	3rd Application
T_1 - Fipronil 40%+ Imidacloprid 40%WG	0.5g	36.67	47.22 (43.40)e	53.33 (43.10)ef	55.00 (47.87)e
T_2 - Chlorantraniliprole 20 SC	0.5ml	40.00	42.78 (40.84)c	46.67 (45.00)c	50.56 (45.31)ed
T_3 - Chlorpyrifos 20 EC	3ml	30.00	34.91 (32.78)a	36.67 (39.23)a	38.33 (37.26)a
T_4 - Azadirachtin 1% EC	1ml	40.00	44.44 (41.80)cde	51.67 (43.10)ed	54.44 (47.55)de
T_5 - (Fipronil 40% + Imidacloprid 40%WG) + Azadirachtin 1% EC	0.5g + 1ml	36.67	46.67 (43.07)de	55.00 (45.96)f	60.00 (50.78)f
T_6 - Chlorantraniliprole 20 SC + Azadirachtin 1% EC	0.5ml + 1ml	36.67	37.92 (37.78)b	40.00 (42.12)b	46.11 (42.75)c
T_7 - Chlorpyrifos 20 EC + Azadirachtin 1% EC	3ml + 1ml	30.00	34.22 (31.67)a	36.67 (37.27)a	38.33 (37.26)a
T_8 - *Bacillus subtilis* 1.5% WS	10ml	36.67	43.33 (41.15)cd	50.00 (41.16)d	51.67 (45.95)cd
T_9 - *Beauveria bassiana* 2% A.S.	10ml	33.33	35.59 (33.89)a	38.33 (39.23)ab	43.33 (41.16)b
T_{10} - Untreated control	-	33.33	51.11 (45.63)f	61.67 (51.75)g	80.56 (64.22)g
CV %		22.85	7.06	2.60	3.92
CD (0.05%)		NS	3.38	2.75	2.10
SEm±		6.60	8.64	1.48	3.26

PTC –Pre Treatment Count
Figures in parentheses are arc sin transformed values

Table.4 Effect of CWSB on yield of coffee (Trial I & II)

Treatments	Dose/litre of water	Yield (Kg/30plants)	
		Trial I	Trial II
T_1 - Fipronil 40% + Imidacloprid 40%WG	0.5g	28.68f	27.85g
T_2 - Chlorantraniliprole 20 SC	0.5ml	37.23cd	40.38d
T_3 - Chlorpyrifos 20 EC	3ml	51.86a	50.86a
T_4 - Azadirachtin 1% EC	1ml	33.56de	32.79f
T_5 - (Fipronil 40% + Imidacloprid 40%WG) + Azadirachtin 1% EC	0.5g + 1ml	30.32ef	29.64g
T_6 - Chlorantraniliprole 20 SC + Azadirachtin 1% EC	0.5ml + 1ml	41.25c	44.06c
T_7 - Chlorpyrifos 20 EC + Azadirachtin 1% EC	3ml + 1ml	52.58a	51.32a
T_8 - *Bacillus subtilis* 1.5% WS	10ml	37.11cd	36.74e
T_9 - *Beauveria bassiana* 2% A.S.	10ml	47.17b	46.94b
T_{10} - Untreated control	-	22.68g	22.40h
CV %		6.70	4.31
CD (0.05%)		4.40	2.83
SEm±		6.56	2.73

Figures in parentheses are arc sin transformed values

Fig.1 Nature of damage due to Coffee White Stem Borer

a. Infested stem showing borer tunnels with grub

b. Ridges formation due to CWSB

c. CWSB Adult

d. Boreholes of CWSB on coffee stem

In both field trial the lower yield was recorded in fipronil 40% + imidacloprid 40% WG (28.68 and 27.85 kg/30 plants) over the untreated control.

Management of coffee white stem borer

In vitro laboratory studies conducted by Seetharama *et al.,* (2004) showed that chlorpyriphos was more effective against eggs, while carbosulfan was more effective against larvae of the fifth instar, and both chlorpyriphos and carbosulfan were effective against adults. chlorpyriphos is more effective and less hazardous than lindane and is recommended for application on the stem during the peak periods of CWSB emergence (Vinod Kumar *et al.,* 2009). Venkatesha and Seetharama (1999) reported that organic insecticides such as chlorpyriphos killed the CWSB's first instar larvae in laboratory conditions for 77-83 days.

CCRI (2017) reported that chlorpyriphos 50 EC and chlorantraniliprole 18.5 SC caused 70.51 per cent mortality of neonate grub of CWSB under laboratory conditions. Our field evaluation of (chlorpyriphos 20 EC + azadirachtin 1% EC), chlorpyriphos 20 EC and chlorantraniliprole 20 SC resulted significant management of CWSB infestations from 45.56% and 55.00% (Trial I), in Trial II from 38.33% and 50.56% respectively. CCRI (2018) recommends the use of non-woven fabric material with a thickness of 0.4 or 1.3 mm for wrapping the

stem of infested plants and spraying with a combination of insecticide (chloripyriphos 50EC + cypermethrin 5EC) @ 1.2 ml per litre, together with 1 ml of any wetting agent, which reduces the infestation by 74-100 percent of adult beetle mortality at the emergency site per exit hole under field conditions.

Venkatesha (1999) reported that for effective control of the pest, management methods are to be improved. Since, the control of CWSB by synthetic insecticides possesses risks due to the coincidence of the flight periods with pre and post-monsoon rains which results in washing of insecticides. In addition, large-scale applications of insecticides kill natural enemies of CWSB and other pests (Venkatesha, 2005).

The strain of *B. bassiana* utilized in our study is IPL/BB/MI-01 with a CFU count of 2×10^8 per ml which resulted in a mortality range between 48.89% (Trial I) and 43.33% (Trial II) under field condition. This is comparable with the study of Aristizabal *et al.,* (1997) where *B. bassiana* strain 'GHA' was used to manage coffee berry borers resulting in 28 per cent mortality (CBB) in field condition in Hawaii and Wei and Kuang (2000) observed that *B. bassiana* caused 90 per cent mortality of *X. quardripes* within 15 days under laboratory conditions in China. In India, CCRI (2017) studied *B. bassiana* under laboratory conditions to manage CBB which resulted in 100 per cent mortality within six days after inoculation and field trials were proposed to evaluate its efficacy. This mortality data depicts the necessity to integrate *B. bassiana* in IPM packages to manage coleopteran pests in coffee ecosystem.

Yield loss from plants infested with coffee white stem borer in Nepal was comparable to that in India and some African countries. In Tanzania, moderately infested coffee plants produced as much as 65% less than non-infested plants (Magina, 2005). Oduor and Simons (1999) reported cumulative yield loss of as much as 77% on coffee farms managed by smallholders in northern Malawi, and Murphy *et al.,* (2008) reported 25% in Zimbabwe.

A study in 90 randomly selected coffee plantations in India showed 45% of plants infested by coffee white stem borer and mean annual yield loss of 35% (Joy, 2004). Indian farmers annually removed more than 9 million coffee plants that cost approximately $40 million to replace and in yield loss (Hall *et al.,* 2006).

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