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Evaluation of insecticides against white stem borer, *Xylotrechus quadripes* (Cerambycidae: Coleoptera) infesting coffee

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Abstract
The coffee white stem borer (CWSB), *Xylotrechus quadripes* (Coleoptera: Cerambycidae), is a major pest of arabica coffee causing considerable losses to the growers and its control has been an issue of significance in the pest management. Among the integrated management strategies, spraying of Chlorpyrifos 20EC at appropriate time will prevent the development of pest. This study was aimed to find out the alternative chemical for Chlorpyrifos 20EC which is being used for more than a decade. The laboratory experiments indicated that insecticides like Phenthoate 50EC, Fipronil 5SC, Thiamethoxam 12.6 + Lambda-Cyhalothrin 9.5 ZC, Chlorpyrifos 50EC + Cypermethrin 5EC and Chlorpyrifos 20EC caused 100% mortality of eggs and it is significantly on par with Ethioprole + Imidacloprid 80WG (98%). In case of neonate larvae, 100 percent mortality was observed in the treatments viz., Phenthoate 50EC, Imidacloprid 17.8SL, Fipronil 5SC, Thiamethoxam 12.6 + Lambda-Cyhalothrin 9.5% ZC, Ethioprole + Imidacloprid 80 WG, Chlorpyrifos 50EC + Cypermethrin 5EC and Chlorpyrifos 20EC. The least mortality was observed in Indoxacarb 14.5 SC among the insecticides tested. The field experiment data revealed that maximum ovicidal and larvicidal action was observed to Chlorpyrifos 50EC + Cypermethrin 5EC and Chlorpyrifos 20EC followed by Phenthoate 50EC and Fipronil 5SC. The least mortality of eggs and neonate larvae was recorded to Novaluron 10 EC and Indoxacarb 14.5 SC. It is, therefore, Chlorpyrifos 50EC + Cypermethrin 5EC, can be utilized as a valuable alternate for Chlorpyrifos 20EC in integrated management of coffee white stem borer.

Keywords: Coffee, insecticides, white stem borer, management

Introduction
Coffee is an important commercial crop and one of the most traded commodity in the world [1]. Among several insect pests reported in coffee, coffee white stem borer (CWSB), *Xylotrechus quadripes* Chevrolat (Cerambycidae: Coleoptera) is considered as a major pest and caused considerable crop loss to the coffee industry [2-5]. The CWSB was first reported in India in 1938 [2]. Apart from India, this pest also occurs in several coffee growing Asian countries like Burma, China, Indonesia, Nepal, Vietnam, Sri Lanka and Thailand [6]. Beside Asia and Africa, recently its occurrence was reported in El Salvador, Honduras, Jamaica, and Mexico [7]. Among *Coffea* species, Arabica coffee (*C. arabica*) is the most preferred and principal host of this pest [8]. The CWSB infestation on Robusta coffee (*C. canephora*) is rarely noticed but when observed the life cycle would not complete. The phenotypical characteristics of Robusta coffee (*i.e*., smooth bark, hard wood) and presence of secondary metabolites would prevent the development of CWSB. Although several hosts were reported but preferential host remains narrow [8].
The CWSB infestation starts by feeding of early instar larvae in the outer surface and gradually bore into stem. As a result of extensive feeding, tunnels are formed inside the stem which affects the nutrient supply and leads to substantial reduction in the yield [9]. The severity of damage depends on the size of the larval population [6]. Severe infestation leads to yellowing of leaves, defoliation and subsequently death of plant [4, 10]. CWSB has two flight periods in India: the pre-monsoon flight period begins in April and extends to the end of May, and the post-monsoon flight starts from the end of September until the end of December or the middle of January [6, 11, 12].
The insecticides spray during adult flight period is one of the critical and essential component for achieving better control of CWSB.

The effectiveness of insecticides to control CWSB is Limited, because the borer feeds and completes the larval and pupal stages inside the plant stem [13]. Due to its concealed nature, it is necessary to target early stages of life cycle (egg and neonate larvae). Laboratory trials of Seetharama *et al*., [14] revealed that Chlorpyrifos 20EC was more effective against eggs, while Carbosulfan 25EC on fifth-instar larvae and both insecticides were effective against adult beetles. Since 2005, Chlorpyrifos 20EC has been recommended for the management of CWSB. In view of this, an alternative insecticide is necessary to avoid the development of resistance in insect. Hence, the present study was aimed to find out the alternative chemical for Chlorpyrifos 20EC by evaluating the efficacy of some new insecticides and insecticide mixtures for the effective management of CWSB.

Materials and Methods

Studies on the evaluation of insecticides against *X. quadripes* were conducted at Central Coffee Research institute, Chikamagaluru during CWSB flight seasons of 2017-2018. The study was carried out both in the laboratory and field conditions. Commercial formulations of the following insecticides were tested for activity against *X. quadripes* eggs and neonate larvae. T_1: Phenthoate 50EC @ 2ml/lt; T_2: Imidacloprid 17.8SL @ 0.5ml/lt; T_3: Fipronil 5SC @1.5ml/lt; T_4: Fluben diamide 19.92 w/w + Thiacloprid 19.92 w/w @ 0.5 ml/lt;T_5: Nova luron 10 EC @ 1 ml/lt;T_6: Indoxacarb 14.5 SC @ 0.75 ml/lt;T_7: Novaluron 5.25 + Indoxacarb 4.5 SC @ 1.5 ml/lt;T_8: Thiamethoxam 12.6% + Lambda-Cyhalothrin 9.5% ZC @ 0.16ml/lt;T_9: Ethioprole + Imidacloprid 80 WG @1.25gm/lt;T_{10}: Chlorpyrifos 50EC + Cypermethrin 5EC @1.2ml/lt; T_{11}: Chlorpyrifos 20EC @ 3ml/lt; T_{12}: Control (water spray).

Evaluation of insecticides under laboratory condition

To evaluate the ovicidal and larvicidal activity of the above selected insecticides, CWSB adults collected from insectary were transferred to insect rearing cages providing with plain white paper for oviposition. Cotton wick dipped in 10% honey solution also placed inside the cage as a feeding substance to the adults. After egg laying, the white sheets were collected and used for the experiment. Under Stereo Microscope, the dead eggs (broken, shrinking, shrivelled or dried) were discarded. Paper with healthy eggs was transferred to Petri-dishes and the insecticides at the desired concentration was sprayed using a hand sprayer. Mortality of the eggs were recorded after 10 days of release. The larvicidal action was tested by spraying the insecticide on the filter paper and after air drying, the neonate larvae were released using a fine brush. Three replications were maintained for each treatment and 50 eggs/neonate larvae collected on *the* same day were used for each replication. Water sprayed eggs and larvae were treated as control.The mortality of the neonate larvae were recorded 24 hrs after treatment spray.

Evaluation of insecticides under field condition

The above selected insecticides were sprayed on the main stem and thick primaries of arabica variety S.795 plants using knapsack sprayer. Experiments were laid out in completely randomized block design with 12 treatments and 3 replications. At periodic intervals, randomly selected treated stem pieces of 7.5cm length and about 2.5 to 3cm diameter were cut and brought to the laboratory for bioassay studies. For each treatment, 5 stem pieces were used and 5 eggs/neonate larvae were released on each stem piece under laboratory condition. The observation on mortality of eggs and neonate larvae of CWSB were recorded on 15th day from date of release.

Data analysis

The mortality data of egg and neonate larvae were subjected to variance analysis. Mean comparisons were performed using the Duncan's Multiple Range Test (DMRT) to examine the differences (P<0.05) among the insecticides.

Results and discussion

Efficacy of Insecticides on eggs and neonate larvae of CWSB

The data from the Table 1 revealed that percent egg mortality of CWSB was observed in the range of 58 to 100 percent after 24 h of spraying and significant differences were found in all the treatments compared over the control (water spray). Among the insecticides, Phenthoate 50 EC, Fipronil 5 SC, Thiamethoxam 12.6% + Lambda-Cyhalothrin 9.5% ZC, Chlorpyrifos 50 EC + Cypermethrin 5EC and Chlorpyrifos 20EC caused 100 percent egg mortality and it is significantly on par with Ethioprole + Imidacloprid 80 WG (98%). The least egg mortality was observed in Indoxacarb 14.5 SC (58%). Likewise, Phenthoate 50EC, Imidacloprid 17.8 SL, Fipronil 5 SC, Thiamethoxam 12.6% + Lambda-Cyhalothrin 9.5% ZC, Ethioprole + Imidacloprid 80 WG, Chlorpyrifos 50EC + Cypermethrin 5EC and Chlorpyrifos 20 EC caused 100% mortality on neonate larvae and significantly differed from Flubendiamide 19.92 w/w + Thiacloprid 19.92 w/w (88%), Indoxacarb 14.5 SC (88%), Novaluron 10 EC (90%) and Novaluron 5.25 + Indoxacarb 4.5 SC (94%). Seetharam *et al*., [14] reported Chlorpyrifos 20EC and Carbosulfan 25EC was more effective against *X. quadripes* eggs and V-instar larvae respectively compared to other insecticides tested. González *et al*., [15] reported Chlorpyrifos 20 EC caused 100% mortality of two and seven days old eggs of the Grapevine wood borer, *X. arvicola* and the efficacy is on par with flufenoxuron and imidacloprid. Further he also reported, Chlorpyrifos 20 EC had a total larvicidal control of *X. arvicola*, differing significantly from the rest of insecticides tested like Spinosad 480 CC, Imidacloprid 20 LS, Pyriproxyfen, Flufenoxuron and Biopesticide, Entomopathogenic fungi *Beauveria bassiana*. In contrary, Poland *et al*., [16] reportedthe density of Asian long horned beetle, *Anoplophora glabripennis* (Coleoptera: Cerambycidae) was significantly reduced in poplar trees (90%), willow trees (83%) injected with Imidacloprid.

Table 1: Efficacy of different insecticides against egg and neonate larvae of CWSB under laboratory conditions

Treatments		Egg mortality (%) (Mean ± SD)	Larval mortality (%) (Mean ± SD)
T_1	Phenthoate 50EC	100 ± 0.00a	100±0.00a
T_2	Imidacloprid 17.8SL	88±3.66ab	100±0.00a
T_3	Fipronil 5SC	100±0.00a	100±0.00a
T_4	Flubendiamide 19.92 w/w + Thiacloprid 19.92 w/w	68± 3.66b	88± 3.66b
T_5	Novaluron 10 EC	64± 6.66b	90± 3.66b
T_6	Indoxacarb 14.5 SC	58± 3.66b	88± 6.66b
T_7	Novaluron 5.25 + Indoxacarb 4.5 SC	76± 6.66b	94± 3.66b
T_8	Thiamethoxam 12.6+ Lambda-Cyhalothrin 9.5% ZC	100±0.00a	100 ±0.00a
T_9	Ethioprole + Imidacloprid 80 WG	98± 6.66a	100 ±0.00a
T_{10}	Chlorpyrifos 50EC + Cypermethrin 5EC	100±0.00a	100 ±0.00a
T_{11}	Chlorpyrifos 20EC	100±0.00a	100 ±0.00a
T_{12}	Control	4± 1.00c	8 ± 2.00c

Note: Means followed by the same letter do not differ significantly at $P = 0.05$ according to DMRT

Evaluation of insecticides under field condition

Data on the mortality of eggs in response to different insecticides are presented in table 2. The field sprayed stem or thick primaries were cut into desirable sizes and brought to the laboratory for bioassay studies. The eggs released on the stems collected after the first day of spray revealed that Phenthoate 50EC, Thiamethoxam 12.6% + Lambda-Cyhalothrin 9.5% ZC, Chlorpyrifos 50EC + Cypermethrin 5EC and Chlorpyrifos 20ECshowed 100 percent mortality and it is significantly on par with Fipronil 5SC (96.67%). The least mortality

was observed in eggs treated with Novaluron 10 EC (50%) followed by Flubendiamide 19.92 w/w + Thiacloprid 19.92 (53.33%) and Indoxacarb 14.5 SC (53.33). The egg mortality after 15 days of spraying revealed that only Phenthoate 50EC, Chlorpyrifos 50EC + Cypermethrin 5EC and Chlorpyrifos 20EC showed more than 80% mortality. All the eggs released on Imidacloprid 17.8SL and Indoxacarb 14.5SC treated stems collected on 42 DAS got hatched into neonate larvae and found feeding inside the stem when observed under stereo microscope. The percent egg mortality on 48 DAS was 43.33 and 33.33 in Chlorpyrifos 50EC + Cypermethrin 5EC and Chlorpyrifos 20EC respectively and it is on par with Fipronil 5SC (33.33%). The highest cumulative egg mortality observed for Chlorpyrifos 50EC + Cypermethrin 5EC (73.75%) and it is significantly on par with the recommended Chlorpyrifos 20EC (71.67%). The least cumulative egg mortality was observed in Indoxacarb 14.5 SC followed by Novaluron 10 EC with 20.83 and 25.83 percent respectively.

The results of insecticide efficacy on survival and feeding of neonate larvae are presented in table 3. The methodology of testing larval mortality remained the same as followed for eggs. The coffee stems treated with Phenthoate 50EC, Chlorpyrifos 50EC + Cypermethrin 5EC and Chlorpyrifos 20EC caused 100% mortality against neonate larvae when released on the first day after spray and it is significantly on par with Imidacloprid 17.8SL (93.33%), Fipronil 5%SC (90%) and Thiamethoxam 12.6% + Lambda-Cyhalothrin 9.5% ZC (90%). The least mortality of neonate larvae of 63.33% was recorded in Ethioprole + Imidacloprid 80WG treated stems. On 42nd DAS, 36.67% and 50% mortality was observed in Chlorpyrifos 20EC and Chlorpyrifos 50EC + Cypermethrin 5EC respectively. The least neonate larval mortality of 3.33 percent was observed in Flubendiamide + Thiacloprid, Indoxacarb, Novaluron + Indoxacarb and Ethioprole + Imidacloprid treated stems. The percent cumulative neonate larval mortality was significantly highest in Chlorpyrifos 50EC + Cypermethrin 5EC (70.83) followed by Chlorpyrifos 20EC (69.58), Fipronil 5SC (59.17%) compared to other insecticides tested. Our results are in line with the work of Reddy *et al*., [17] reported, Chlorpyrifos 50EC + Cypermethrin 5EC (0.9 and 1.2 ml/litre of water) and Chlorpyrifos 20EC at 3ml/l recorded highest egg and larval mortality up to 42nd DAS among the insecticides tested against *X. quadripes.* Poland *et al.,* [18] described that Imidacloprid produced 60% and 100% mortality against *A. glabripennis* and *P. scalator* larvae respectively, even after 14 weeks of spray. He further explained wood feeding Cerambycid larvae required long periods of exposure to the insecticide to get killed. Our results alsorevealedthat most of the tested insecticides are effective to the CWSB egg and neonate larva at the initial period and the efficacy is coming down when the days are progressed. Based on our results, Chlorpyrifos 50EC + Cypermethrin 5EC is on par statistically with the recommended Chlorpyrifos 20EC and it has a long field persistence compared to other insecticides sprayed on coffee stems. Lu *et al*., [19] reported that that the Chlorpyrifos residues dissipated significantly in the first few days and persisted in the crops for extended period of time. The initial deposit of the insecticides after spraying varied with different crops (Annuals, Biennial, Perennials), parts of the plants (Leaf, fruit, stem, root feeding), mode of application (granular, liquid, fumigants), type of the sprayer and nozzle used and several other factors could be considered. Based on these factors, it is presumed that efficacy of the insecticides is directly proportional to the initial deposition of the chemical on coffee stem. One of the key factors for decreased toxicity could be photo degradation of insecticides [20]. This study emphasizes the use of insecticide mixtures (Chlorpyrifos 50EC + Cypermethrin 5EC) as alternative chemical for the management of CWSB. However, effects of such insecticide mixtures on other organisms and biological control agents should be checked under field conditions.

Table 2: Efficacy of different insecticides against eggs of *X. quadripes*

Sl. No.	Percent mortality of CWSB eggs at regular intervals/Days after spraying (DAS)								
	1 DAS	7 DAS	14 DAS	21 DAS	28 DAS	35 DAS	42 DAS	48 DAS	Cumulative
T_1	100 ± 0.00a	90.00 ± 5.77a	83.33± 3.33ab	73.33 ± 3.33a	56.66 ± 3.33c	43.33 ± 3.33b	23.33 ± 3.33c	10.00 ± 5.77b	60.00 ± 3.53b
T_2	76.67 ± 3.33b	73.33 ± 3.33b	50.00 ± 5.77c	43.33 ± 3.33c	30.00± 5.77de	20.00 ± 0.00cde	0.00 ± 0.00e	0.00± 0.00b	36.67± 2.69c
T_3	96.67 ± 3.33a	83.33 ± 3.33ab	76.67 ± 3.33ab	63.33 ± 3.33b	60.00 ± 0.00 bc	46.67 ± 6.67b	36.67 ± 3.33b	33.33 ± 6.67a	62.08 ± 3.75b
T_4	53.33 ± 3.33d	53.33 ± 6.67c	46.67 ± 6.67c	40.00 ±5.77cd	23.33 ± 3.33fgh	23.33 ± 3.33cd	16.67 ± 3.33cd	6.67 ± 3.33b	32.92 ± 4.47c
T_5	50.00 ± 5.77d	43.33 ± 3.33c	33.33 ± 3.33de	33.33 ± 3.33cd	23.33 ± 3.33fgh	13.33 ±3.33de	10.00 ± 0.00de	0.00 ± 0.00b	25.83±2.81cd
T_6	53.33 ± 3.33d	43.33± 3.33c	26.67 ± 3.33ef	20.00 ± 0.00e	13.33 ± 3.33hi	10.00 ± 0.00e	0.00± 0.00ee	0.00 ± 0.00b	20.83 ± 1.67cd
T_7	63.33 ± 6.66c	53.33 ± 3.33c	43.33 ± 3.33cd	33.33± 3.33cd	16.67 ± 3.33ghi	10.00 ± 0.00e	3.33 ± 3.33e	0.00 ± 0.00b	27.92 ± 2.92cd
T_8	100.00 ± 0.00a	76.67 ± 3.33b	73.33 ± 3.33b	63.33 ±3.33b	36.67 ± 3.33d	30.00 ± 5.77c	16.67 ± 3.33cd	13.33 ± 3.33b	51.25 ± 3.22bc
T_9	83.33± 3.33b	56.67 ± 3.33c	46.67 ± 3.33c	30.00 ± 5.77de	26.67 ± 3.33def	16.67 ± 3.33de	3.33 ± 3.33e	0.00 ± 0.00b	32.92 ± 3.22c
T_{10}	100.00 ± 0.00a	96.67 ± 3.33a	83.33 ± 3.33ab	76.67 ± 3.33a	73.33 ± 3.33a	63.33 ± 3.33a	53.33 ± 3.33a	43.33 ± 3.33a	73.75 ± 2.92a
T_{11}	100.00 ± 0.00a	93.33 ± 6.67a	86.67 ± 3.33a	80.00 ± 0.00a	70.00 ± 5.77ab	63.33 ± 3.33a	46.67 ± 8.82ab	33.33 ± 8.82a	71.67 ± 4.59a
T_{12}	6.67 ± 3.33e	13.33 ± 3.33d	16.67 ± 3.33f	6.67± 3.33f	6.67 ± 3.33i	16.67 ±3.33de	16.67 ± 3.33cd	6.67 ±3.33b	11.25 ± 3.33e

Note: Means followed by the same letter do not differ significantly at $P = 0.05$ according to DMRT

Table 3: Efficacy of different insecticides against neonate larvae of *X. quadripes*

Sl. No.	Percent mortality of neonate larvae of CWSB at regular intervals/Days after spraying (DAS)								
	1 Das	7 Das	14 Das	21 Das	28 Das	35 Das	42 Das	48 Das	Cumulative
T_1	100.00 ± 0.00a	83.33 ± 3.33a	66.67 ± 8.82bc	66.67 ± 3.33ab	56.67 ± 3.33ab	36.67 ± 3.33cd	30.00 ± 5.77bc	16.67 ± 3.33de	57.08 ± 3.91b
T_2	93.33 ± 6.67a	66.67 ± 3.33bc	63.33 ± 3.33bc	50.00 ± 5.77cd	40.00 ± 11.55bc	26.67 ±6.67de	20.00 ± 0.00cde	20.00 ± 0.00cd	47.50 ± 4.67c
T_3	90.00 ± 5.77a	86.67 ± 3.33a	73.33 ±3.33ab	63.33 ± 3.33bc	56.67 ± 6.67ab	43.33 ± 3.33bc	30.00 ± 5.77bc	30.00 ± 5.77bc	59.17 ± 4.67b
T_4	70.00 ± 5.77bc	60.00 ± 5.77bc	56.67 ± 3.33c	40.00 ± 5.77de	33.33 ± 6.67c	20.00 ± 0.00e	16.67 ± 3.33de	3.33 ± 3.33f	37.50 ± 4.25de
T_5	76.67 ± 3.33b	63.33 ± 3.33bc	33.33± 3.33d	40.00 ± 0.00de	26.67 ± 3.33cd	20.00 ±0.00e	13.33 ± 3.33ef	6.67 ± 3.33ef	35.00 ± 2.50ef
T_6	60.00 ± 0.00c	46.67 ± 3.33d	26.67 ± 3.33d	26.67 ±6.67e	16.67 ± 3.33e	16.67 ± 3.33ef	10.00 ± 0.00ef	3.33 ± 3.33f	25.83 ± 2.92g
T_7	60.00 ± 5.77c	46.67 ± 6.67d	40.00 ± 0.00d	36.67 ± 8.82de	26.67 ± 6.67cd	26.67 ± 6.67de	20.00 ± 0.00cde	3.33 ± 3.33f	32.50 ± 4.74f
T_8	90.00 ±5.77a	70.00 ± 5.77b	66.67 ± 3.33bc	36.67 ± 3.33de	40.00 ± 0.00bc	36.67 ± 3.33cd	26.67 ± 3.33bcd	20.00 ± 0.00cd	48.33± 3.11c
T_9	63.33 ± 3.33c	56.67 ± 3.33cd	56.67 ± 8.82c	50.00 ± 5.77cd	40.00 ± 0.00bc	30.00±5.77de	20.00 ±0.00cde	3.33 ± 3.33f	40.00 ± 3.80d
T_{10}	100.00 ± 0.00a	90.00±0.00a	83.33 ± 3.33a	73.33 ± 3.33ab	66.67 ± 3.33a	53.33 ±3.33ab	50.00 ± 5.77a	50.00 ± 5.77a	70.83 ±3.11a
T_{11}	100.00 ±0.00a	90.00 ±0.00a	86.67 ± 3.33a	80.00 ±0.00a	66.67 ± 3.33a	63.33 ± 3.33a	36.67 ± 3.33ab	33.33 ± 6.67b	69.58 ± 2.50a
T_{12}	3.33 ± 3.33d	6.67 ± 3.33e	3.33 ± 3.33e	6.67 ± 3.33f	6.67 ± 3.33e	6.67 ± 3.33f	3.33 ± 3.33f	6.67 ± 3.33ef	5.42 ± 3.33h

Conclusion
The findings of the present study clearly indicated that Chlorpyrifos 50EC + Cypermethrin 5EC, can be utilized as a valuable alternate for Chlorpyrifos 20EC in integrated management of coffee white stem borer.

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