Laboratory evaluation of pesticides on oviposition, egg mortality and feeding deterrence on cashew stem and root borer, *Plocaederus ferrugenius* L. (Coleoptera: Cerambycidae)

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Cashew stem and root borers namely, *Plocaederus ferrugenius* L. and *P. obesus* Gahan (Coleoptera: Cerambycidae) are major pests of cashew (*Anacardium occidentale* L.) world wide. The larvae of these pests feed on the vital bark tissues of main stem, primary branches and primary roots of cashew trees, thereby causing hindrance in the flow of plant sap with reduced translocation of nutrients, leading to premature canopy yellowing, leaf fall and drying of the twigs followed by gradual death of infested cashew trees. (Ayyanna and Ramadevi, 1986) Due to death of pest infested trees, the density of yielding cashew trees reduces drastically which in turn causes substantial reduction in cashew nut productivity. These pests are internal feeders and their initial symptoms of damage are generally inconspicuous. Hence, the pest evades timely detection by the cashew farmers.

Several management strategies including biological, cultural and mechanical methods were tried against CSRB. Integrated pest management (IPM) strategies (Ayyanna and Ramadevi, 1986; Sundararaju, 2002; Mohapatra, 2004; NRCC, 2004), prophylactic measures (Samiayyan *et al*., 1991; Senguttuvan, 1999; Sundararaju *et al*., 1999, Mohapatra and Jena, 2008) and syntheitic pesticides (Rajapakshe, 1997) are some among them.

Due to the global concern about residual effects of insecticides, pest management currently focuses on use of safer pesticides and biopesticides. Keeping this in view, the present study was aimed at comparative evaluation of two neem oil based bio-pesticides, a cow urine derivative and three synthetic insecticides for their efficacy in influencing various biological activities of CSRB.

Laboratory studies were done using laboratory reared test insects during 2010-11 at the Directorate of Cashew Research, Puttur, India. Straight cashew sticks of 30 cm length and 9 cm diameter were collected from healthy cashew trees in order to provide niche for oviposition by the CSRB adults. A cotton tape (2 cm wide) was spirally wound onto these sticks as per the method standardized by Raviprasad and Bhat (2007). Freshly prepared test solutions of chlorpyriphos (0.1% and 0.2%), carbaryl (0.1% and 0.2%), monocrotophos (0.1% and 0.2%), as well as neem oil based biopesticides, *viz*., Nimbecidine (3 ml l^{-1} and 5 ml l^{-1}) and Multineem® (3 ml l^{-1} and 5 ml l^{-1}), 'arka' (15 ml l^{-1}) (a cow urine derivative containing carbolic acid and manganese, which possess pesticidal activity - Mahurker, 2006) were used for the evaluations. The test solutions were sprayed with hand sprayer onto cashew sticks prepared for egg laying (oviposition sticks) which were air dried under shade in separate trays and labeled suitably for further evaluations. Oviposition sticks without pesticide treatment were also prepared separately for use as untreated check.

Two uniform aged mated female beetles and one male beetle of *P. ferrugenius* were released for free choice oviposition into aluminum cages

(25 x 15 x 15 cm LBH) having one treated oviposition stick and an untreated oviposition stick as control. Cotton dipped in 20 per cent honey was provided as adult feed. The number of eggs laid after 24 h in treated and untreated sticks in each rearing cage was recorded. The treated oviposition sticks were collected from the main treated lot on specified intervals *i.e*., 1, 3, 5, 7, 10, 15, 20, and 25 day after treatment (DAT) and looked for oviposition in three replications to evaluate oviposition repellence in case of each treatment. Statistical analysis of data was done by using SAS software and comparison of efficacy of various treatments was done by calculating the square root ($\sqrt{x+0.1}$) for every interval.

In order to estimate the post treatment egg mortality in different insecticidal treatments, the eggs collected from laboratory insect cultures of CSRB beetles were placed beneath the cotton tape wound around the treated oviposition sticks (@ 8 eggs stick^{-1}) on 1, 3, 5, 7, 10, 15 and 20 DAT for evaluating egg mortality. The number of CSRB eggs which were unhatched (as indicated by blackening of eggs) were recorded after 7-10 days of placing eggs, while, the hatching of eggs were confirmed by presence of chewed powdery frass produced on the cashew sticks due to feeding of bark by nascent CSRB larvae. Percentage of unhatched eggs was determined. Untreated oviposition sticks were also maintained as control and observations were recorded in three replications. The percentage egg mortality and its respective arc-sine value were calculated and statistically analysed using SAS software for each interval of treatment.

The nascent larvae of CSRB obtained from laboratory cultures were used for this trial. Cashew bark obtained from the healthy cashew trees were cut into pieces measuring approximately 1.5 x 1.5 x 1.5 cm. These were subsequently sprayed with various concentrations of freshly prepared test insecticide solutions and air dried under shade. For testing the feeding deterrence, eight nascent larvae were released individually into small depression made on the insecticide treated bark pieces. Eight such bark pieces were placed per Petri plate and prevented from drying by water mist spray on to the lid of the Petri plate on alternate days.

Trials were repeated by placing the nascent CSRB larvae on 1, 3, 5, 7, 10, 15, 20 and 25 DAT which were replicated thrice. Successful feeding by the nascent larvae as indicated by exudation of powdery frass was recorded daily. Statistical analysis was done for comparison of various treatments using SAS software after transforming the percentage feeding by the larvae to arc-sine values.

Oviposition deterrence

One day after treatment (DAT), synthetic pesticides such as chlorpyriphos (0.1 and 0.2%), monocrotophos (0.2%), carbaryl (0.1%), Multineem (5 ml l^{-1}) and Nimbecidine (3 ml and 5 ml l^{-1}) resulted in least oviposition (0.32 eggs each), mutually on par and were significantly different from the other test insecticides. The maximum egg laying was noticed in case of untreated control (4.13 eggs) which was significantly different from all the other treatments. The treatments *viz*., carbaryl (0.1%), monocrotophos (0.2%), chlorpyriphos (0.1 and 0.2%), Multineem (5 ml l^{-1}) and Nimbecidine (3 ml and 5 ml l^{-1}) were on par with minimum oviposition (0.32 eggs) at 3 DAT. Multineem (3 ml l^{-1}), monocrotophos (0.1%), 'arka' (15 ml l^{-1}) showed less efficacy, but were significantly different from the control. On 5 DAT, chlorpyriphos (0.1% and 0.2%), monocrotophos (0.2%) and Nimbecidine (3 ml and 5 ml l^{-1}) retained significantly consistent efficacy whereas, Multineem (5 ml l^{-1}), monocrotophos (0.1%), carbaryl (0.1%), and ''arka'' (15 ml l^{-1}) were on par but significantly different from control. Multineem (3 ml l^{-1}) was on par with untreated control.

The results at 7 DAT indicated that chlorpyriphos (0.1 and 0.2%), monocrotophos (0.2%), Nimbecidine (5 ml l^{-1}) retained effective oviposition repellence, while Multineem (3 ml l^{-1} and 5 ml l^{-1}), Nimbecidine (3 ml l^{-1}) and ''arka'' (15 ml l^{-1}) were on par. Monocrotophos (0.1%), carbaryl (0.1%) and Multineem (5 ml l^{-1}), showed oviposition deterrence however, they were not significantly different from the untreated control. On 10 DAT, chlorpyriphos (0.1 and 0.2%), monocrotophos (0.2%), Multineem (3 ml l^{-1} and 5 ml l^{-1}) and Nimbecidine (5 ml l^{-1}) were on par, however with the exception of ''arka'', the bio-pesticides were significantly different from the untreated control with regard to oviposition deterrence.

Chlorpyriphos (0.1 and 0.2%) showed significant oviposition deterrence at 15 DAT which was on par with monocrotophos (0.2%) and also with the bio-pesticides; Nimbecidine (5 ml l^{-1}), Multineem (5 ml l^{-1}). Further, monocrotophos (0.1%), Nimbecidine (3 ml l^{-1}), Multineem (3 ml l^{-1}) and carbaryl (0.1%) were on par with each other. ‘‘arka’’ (15 ml l^{-1}) and carbaryl (0.1%) were on par with control. At 20 DAT, chlorpyriphos (0.1% and 0.2%) monocrotophos (0.2%) and Multineem (5 ml l^{-1}) and Nimbecidine (5 ml l^{-1}) showed on par supremacy with efficient oviposition deterrence (<1.33 eggs). Carbaryl (0.1%) and Nimbecidine (3 ml l^{-1}) showed least oviposition and were on par with control. The observations at 25 DAT revealed that, efficacy of the insecticides was not consistent in comparison to the previous trend displayed by both synthetic insecticides and bio-pesticides. All the insecticides at any particular concentration showed a considerable decrease over a period of time, due to loss of repellence activity (Table 1).

Egg mortality induction

The treatment with synthetic insecticides, chlorpyriphos (0.1% and 0.2%) and monocrotophos (0.1% and 0.2%) prevented egg hatching significantly up to 3 DAT, chlorpyriphos (0.1% and 0.2%) treated sticks revealed 100 per cent egg mortality up to 7 DAT. On 1 DAT, monocrotophos (0.1% and 0.2%) chlorpyriphos (0.1% and 0.2%) Multineem (3 ml l^{-1} and 5 ml l^{-1}) were on par. Carbaryl (0.1% and 0.2%) and Nimbecidine (3 ml l^{-1} and 5 ml l^{-1}) were not statistically different. ‘‘arka’’ (15 ml l^{-1}) was on par with carbaryl (0.1%) and Nimbecidine (3 ml l^{-1}). However, ‘‘arka’’ (15 ml l^{-1}) did not differ statistically from the untreated control in inducing egg mortality.

Among the synthetic insecticides, chlorpyriphos (0.1% and 0.2%), monocrotophos (0.1% and 0.2%) showed maximum egg mortality. Carbaryl (0.2%) was on par with Multineem (3 ml l^{-1} and 5 ml l^{-1}) and Nimbecidine (5 ml l^{-1}) which were significantly different from the control.

At 5 DAT, chlorpyriphos (0.1% and 0.2%), monocrotophos (0.2%) and carbaryl (0.2%) were consistent in their effect and were on par with each other. Further, monocrotophos (0.1%), Nimbecidine (3 ml l^{-1} and 5 ml l^{-1}), carbaryl (0.1%) ‘‘arka’’ (15 ml l^{-1}), Multineem (5 ml l^{-1}) were on par with carbaryl (0.2%). ‘‘arka’’ (15 ml l^{-1}), Nimbecidine (3 ml l^{-1}) and Multineem (3 ml l^{-1} and 5 ml l^{-1}) were not statistically different from the untreated control. During the further interval of 7 DAT, chlorpyriphos (0.1% and 0.2%) showed consistently highest efficacy on egg mortality, which was significantly different from all the other treatments. Monocrotophos (0.2%), carbaryl (0.1% and 0.2%) Nimbecidine (3 ml l^{-1} and 5ml l^{-1}), Multineem 5 ml l^{-1} and ‘‘arka’’ (15 ml l^{-1}) were found to be on par with each other. Chlorpyriphos (0.1% and 0.2%) could retain their superiority in egg mortality up to 15 DAT,

Table 1. Comparative efficacy of various insecticides on oviposition by *P. ferrugenius*

Pesticides evaluated	Mean number of eggs laid							
	1 DAT	3 DAT	5 DAT	7 DAT	10 DAT	15 DAT	20 DAT	25 DAT
Carbaryl (0.1%)	0.32 a	0.32 a	1.44 b	1.76 cd	3.33 de	2.66 cd	3.18 d	4.24 de
Monocrotophos (0.1%)	1.44 bc	1.44 bc	1.44 bc	1.44 bcd	2.66 bcde	1.94 bc	1.44 bc	4.90 e
Monocrotophos (0.2%)	0.32 a	0.32 a	0.32 a	0.32 a	0.32 a	1.04 ab	1.2 a	2.02 a
Chlorpyriphos (0.1%)	0.32 a	0.32 a	0.32 a	0.32 a	0.32 a	0.32 a	0.32 a	3.93 de
Chlorpyriphos (0.2%)	0.32 a	0.32 a	0.32 a	0.32 a	0.32 a	0.32 a	0.32 a	1.56 a
Multi-neem ® (3ml l^{-1})	2.10 c	2.46 d	1.85 cd	1.04 b	1.32 abc	1.66 bc	1.76 bc	2.73 abcd
Multi-neem® (5ml l^{-1})	1.04 ab	0.87 ab	1.04 b	1.55 bcd	1.15 ab	1.04 ab	1.33 ab	2.10 ab
Nimbecidine (3ml l^{-1})	0.32 a	0.32 a	0.32 a	1.2 bc	2.02 bcd	1.55 bc	2.37 bcd	3.57 bcde
Nimbecidine(5ml l^{-1})	0.32 a	0.32 a	0.32 a	0.32 a	1.20 abc	1.32 ab	1.33 ab	2.37 abc
"arka" (15ml l^{-1})	1.44 bc	1.85 bcd	1.55 bcd	1.44 bcd	2.46 bcd	2.70 cd	1.66 bc	3.91 cde
Control	4.13 d	2.66 d	2.02 cd	2.02 d	3.84 e	3.80 d	1.58 bc	3.05 abcd
CD (0.05)	0.7777	0.9932	0.5175	0.6634	1.5136	1.1805	1.0691	1.54061

Figures are $\sqrt{x + 0.1}$ transformed values; Figures followed by the same alphabets in a column are statistically on par however, the other synthetic and bio-pesticides showed varying levels of egg mortality. During the observations of 20 DAT, influence of chlorpyriphos (0.1% and 0.2%) on egg mortality had receded, resulting in only 50 per cent efficacy in inducing egg mortality in comparison to its earlier effectiveness. The treatments involving carbaryl (0.1% and 0.2%). monocrotophos (0.1%), Multineem (3 ml l^{-1}) and Nimbecidine (3 ml l^{-1}) were on par with each other and with the control on 20 DAT (Table 2).

Table 2. Comparative efficacy of various insecticides on egg morality of *P. ferrugenius*

Pesticide evaluated	Mean percentage egg mortality						
	1 DAT	3 DAT	5 DAT	7 DAT	10 DAT	15 DAT	20 DAT
Carbaryl (0.1%)	53.65 bc	40.75 cd	42.88 bc	26.38 bcd	15.29 c	22.02 de	18.63 de
Carbaryl (0.2%)	59.44 b	59.44 b	61.04 ab	41.81 b	41.81 b	30.91 bcd	19.48 cde
Monocrotophos (0.1%)	90.00 a	90.00 a	49.81 bc	14.50 d	31.85 b	27.27 de	24.62 bcde
Monocrotophos (0.2%)	90.00 a	90.00 a	90.00 a	27.28 bcd	42.28 bc	24.62 cd	29.08 bc
Chlorpyriphos (0.1%)	90.00 a	90.00 a	90.00 a	90.00 a	73.40 a	62.73 a	51.05 a
Chlorpyriphos (0.2%)	90.00 a	90.00 a	90.00 a	90.00 a	80.43 a	62.73 a	51.05 a
Multi-neem® (3ml l^{-1})	90.00 a	46.54 bcd	25.50 cd	17.79 d	29.08 bc	22.88 de	22.02 bcde
Multi-neem® (5ml l^{-1})	90.00 a	56.44 bc	36.68 bcd	26.38 bcd	30.92 bc	23.75 de	28.18 bc
Nimbecidine (3ml l^{-1})	53.65 bc	34.71 de	38.68 bcd	30.92 bcd	38.68 b	39.71 bc	22.89 bcde
Nimbecidine (5ml l^{-1})	64.52 b	43.97 bcd	46.24 bc	40.75 bc	42.88 b	43.98 b	30.92 b
"arka" (15ml l^{-1})	39.71 cd	41.81 cd	39.71 bcd	25.50 bcd	17.04 c	16.12 e	24.62 bcde
Control	18.63 d	18.63 e	14.48 d	19.47 d	15.30 c	15.30 e	17.04 e
LSD (0.05)	17.953	17.336	27.368	20.199	16.377	14.498	10.446

Figures are arc sine transformed values; Figures followed by the same alphabets in a column are statistically on par

Feeding repellence

Efficacy of insecticides in deterring feeding by the nascent larvae of CSRB which were released on treated bark pieces was observed to be 100 per cent up to 7 DAT in case of chlorpyriphos (0.2%) only. Chlorpyriphos (0.1%) showed 100 per cent efficacy up to 3 DAT, and carbaryl (0.1%), monocrotophos (0.1% and 0.2%), Nimbecidine (3 ml l^{-1} and 5 ml l^{-1}), Multineem (3 ml l^{-1} and 5 ml l^{-1}) and ‘‘arka’’ (15 ml l^{-1}) were on par and all these treatments were significantly different from control. On 5 DAT, chlorpyriphos (0.1% and 0.2%) were on par with monocrotophos (0.2% and 0.1%) and Multineem (5 ml l^{-1}) while the other insecticidal treatments were significantly different from the control. A similar trend of chlorpyriphos (0.1% and 0.2%) and monocrotophos (0.2%) being most effective continued till 20 DAT. Treatment with ‘‘arka’’ (15 ml l^{-1}) was on par with the untreated control on 15 DAT. With the exception of chlorpyriphos (0.1% and 0.2%), all the other treatments were found to be on par with each other and with the untreated control at 25 DAT. Feeding deterrence trials indicated that chlorpyriphos (0.2%) could effectively deter feeding up to 25 DAT with minimum percentage of grub feeding the treated bark (12.02) without feeding up to 7 DAT. Among the biopesticides tested, Multineem was on par with chlorpyriphos and monocrotophos up to 5DAT. However, in comparison with the synthetic organophosphate insecticides, biopesticides could not cause significant feeding deterrence to the nascent larvae of CSRB (Table 3).

The present investigations revealed chlorpyriphos was efficient in repelling oviposition, in preventing egg hatching and deterring feeding by the CSRB larvae. Higher durations (20 DAT) of oviposition repellence in chlorpyriphos and monocrotophos treatments were observed which are higher than reported earlier for these chemicals (NRCC, 2004). Mohapatra *et al.* (2004) reported that chlorpyriphos (0.2%) was the most effective pesticide in protecting 88.13 per cent of treated CSRB infested cashew trees from further re-infestation in Orissa. Mohapatra and Jena (2007) reported application of monocrotophos, chlorpyriphos and neem oil (crude) to effectively manage the CSRB. They reported that cow urine at 25, 50 and 75 per cent concentration and chlorpyriphos treated trees have displayed significantly higher yield than control. Field efficacy

Table 3. Comparative efficacy of various insecticides on feeding by the larvae of *P. ferrugenius*

Pesticide Evaluated	Mean percentage feeding							
	1 DAT	3 DAT	5 DAT	7 DAT	10 DAT	15 DAT	20 DAT	25 DAT
Carbaryl (0.1%)	19.47 bc	27.28 bc	35.68 b	27.28 bc	22.02 ab	41.81 d	35.68 bc	56.44 c
Carbaryl (0.2%)	22.02 bc	32.80 c	30.00 b	27.28 bc	22.02 ab	41.81 d	35.68 bc	56.44 c
Monocrotophos (0.1%)	16.96 bc	27.28 bc	7.18 a	9.60 ab	22.02 ab	16.96 abc	22.02 abc	56.44 c
Monocrotophos (0.2%)	12.02 ab	27.28 bc	7.18 a	4.78 a	14.48 ab	9.60 ab	22.02 abc	38.68 abc
Chlorpyriphos (0.1%)	0.00 a	0.00 a	2.39 a	9.60 a	14.48 ab	12.02 ab	14.48 ab	17.26 ab
Chlorpyriphos (0.2%)	0.00 a	0.00 a	0.00 a	0.00 a	4.78 a	4.78 a	4.78 a	12.02 a
Multineem® (3ml l^{-1})	16.96 bc	7.18 b	41.81 b	32.80 cd	41.81 c	41.81 d	38.78 bc	35.68 abc
Multineem® (5ml/ l^{-1})	24.63 bc	30.00 bc	9.60 a	35.68 cd	30.00 bc	32.80 bcd	19.47 abc	35.68 abc
Nimbecidine (3ml l^{-1})	24.63 bc	27.28 bc	30.00 b	38.68 cd	32.80 bc	41.81 d	38.68 bc	48.59 c
Nimbecidine (5ml l^{-1})	32.80 c	27.28 bc	30.00 b	27.28 bc	24.63 bc	38.68 cd	32.80 bc	41.81 bc
"arka" (15ml l^{-1})	27.28 bc	24.63 bc	45.10 b	35.68 cd	30.00 bc	52.34 de	45.10 c	56.43 c
Control	61.04 d	90.00 d	90.00 c	90.00 e	56.43 d	73.40 e	73.40 d	52.34 c
LSD (0.05)	16.340	23.736	20.390	19.703	18.658	24.695	27.326	28.889

Figures are arcsine transformed values; Figures followed by the same alphabets in a column are statistically on par

of chlorpyriphos (0.2%) and monocrotophos (0.2%) as post extraction prophylaxis, involving removal of pest stages from infested cashew trees followed by insecticidal treatment; under IPM of CSRB was reported by Raviprasad *et al*. (2009). Samiayyan *et al*. (1991) reported that field treatment with carbaryl did not show significant effect against cashew stem and root borer. The results of the present study agreed with this report.

Mohapatra (2004) reported that, eco-friendly management of CSRB in Orissa using a combination of pesticides with neem oil led to highest recovery of treated trees. In the present study, chlorpyriphos and neem based bio-pesticides indicated on par efficacy, with less number of oviposition (<1.33) on 20 DAT. Neem based pesticides and 'arka' are recognized as bio-pesticides in India. It was reported that neem seed extract, neem leaf extract and cow urine in alternate combination with pesticide formulations could effectively deter incidence of mustard aphid, *Lipaphis erysimi* Kal. (Gupta, 2005) Nimbecidine was reported to be effective against rice pests in Sikkim (Kalita *et al.*, 2009). The results of the present study agree with this report.

Sahu and Sharma (2008) reported the usage of neem cake in IPM schedule against CSRB. The results of the present study revealed that Nimbecidine was a better oviposition deterrent rather than a feeding repellent of the CSRB larvae. Murugesan and Murugesan, (2009) reported that field application of Nimbecidine (2 ml l^{-1}) was able to reduce the shoot damage by brinjal fruit borer, *Leucinodes orbonalis* Guenee (Lepidoptera: Pyrallidae) by more than 50 per cent. They also reported that, consistent effect was observed only for neem oil (57.29%) and Nimbecidine (52.67%). Neem based biopesticides were used against cotton pests (Gahukar, 2000). Gahukar (2010) reported the bio efficacy of natural products derived from neem and other tropical trees on insect pests and diseases attacking forest trees in India.

The application of botanicals including neem extracts and cow urine for the management trials on stem borer, *Chilo partellus* Swinhoe in sweet sorghum; was reported by Jose *et al.* (2008), in which, Nimbecidine 5 ml l^{-1} (12.8% azadiractin) was found to be on par with the standard check; endosulfan 35 EC (12.83%). Garima and Ram (2006) evaluated the efficacy of cow urine against stem borers and cost benefit in soybean production in comparison to conventional insecticide (chlorpyriphos) and biopesticide (Dipel).

All the synthetic pesticides evaluated in this study displayed higher levels of oviposition repellence, egg mortality and feeding deterrence of the CSRB than the neem oil based and cow urine based bio-pesticides. Nimbecidine (5ml l^{-1}) could exhibit oviposition repellence up to 15 DAT which was on par with that of monocrotophos (0.2%), chlorpyriphos (0.1% and 0.2%) and need to be confirmed for field efficacy. Among all the pesticides tested, chlorpyriphos (0.2%) exhibited significantly higher efficacy in oviposition repellence, egg mortality induction and feeding deterrence.

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