RELATIVE SUSCEPTIBILITY OF TEA MOSQUITO BUG, *HELOPELTIS THEIVORA* WATERHOUSE AND RED SPIDER MITE, *OLIGONYCHUS COFFEAE* NIETNER EGGS TO COMMONLY USED PESTICIDES

Somnath Roy[1], Ananda Mukhopadhyay [1], Guruswami Gurusubramanian[2]*

[1] Entomology Research Unit, Department of Zoology, University of North Bengal
Darjeeling-734013, West Bengal, India
[2] Department of Zoology, Mizoram Central University, Tanhril, Aizawl -796 009, Mizoram, India

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Abstract: The tea mosquito bug (*Helopeltis theivora* Waterhouse) and red spider mite (*Oligonychus coffeae* Nietner) are the two major pests of tea (*Camellia sinensis* L.). Their intensity of infestation was increasing day by day in an alarming proportion and increasing resistance to pesticides constitutes a serious problem in North Bengal tea plantations, India. One of the insecticide resistance management strategies is the use of chemicals that can effectively control the pest in the initial life stage (egg stage). However most of the earlier studies were done to control the mobile stages of *H. theivora* and *O. coffeae*. The present experiment was conducted to evaluate the effectiveness of acaricides/insecticides in killing its eggs. On the basis of LC_{50} values, the descending order of ovicidal toxicity of different commonly used insecticides to *H. theivora* eggs were: etofenprox, β-cyfluthrin, cypermethrin, imidacloprid, fenpropathrin, λ-cyhalothrin, deltamethrin, profenofos, monocrotophos, thiomethoxam, alphamethrin, dimethoate, quinalphos, chlorpyriphos, oxydemeton methyl, acephate, azadirachtin and endosulfan. In case of *O. coffeae* eggs the lowest LC_{50} value was determined for fenazaquin, which was followed by profenophos, propargite, fenpropathrin, ethion, dicofol, abamectin and finally by azadirachtin. The data obtained in the present study may be used as a tool of IRM (integrated resistance management) strategies that can effectively control the pests in the initial stage itself (egg stage).

Key words: tea pests, ovicides, *Helopeltis theivora, Oligonychus coffeae*

INTRODUCTION

The tea mosquito bug, *Helopeltis theivora* Waterhouse (Heteroptera: Miridae) and red spider mite *Oligonychus coffeae* Nietner (Acarina: Tetranychidae) are the most dreaded polyphagous pests in plantation crops. Particularly, these are the most damaging pests of tea (*Camellia sinensis* L.) plantation causing substantial (25–50%) crop loss in India. If populations of these pests are not controlled, they can cause a total loss of yield (Gurusubramanian *et al.* 2008).

Nymphs and adults of *H. theivora* suck the sap of young leaves, buds and tender stems and while doing so, it inject toxic saliva which causes the breakdown of tissues surrounding the puncture, which becomes dark brown shrunken spots after 24 hours. Badly affected leaves become deformed and even curl-up. In a severe attack, bushes virtually cease to form shoots and the affected area may not flush for weeks. The egg of *H. theivora* is sausage-shaped, dull white and has two unequal chorionic processes. Eggs are laid in the tissue of the shoot and the chorionic processes project outside with longer process above the shorter one. The operculum or the saucer shaped lid remains at the level of the substratum or slightly sunken. The most preferred site of oviposition is a soft part of the shoot below the second leaf and the exposed tissues after a harvest (Bhuyan and Bhattacharyya 2006). In addition, due to oviposition, tender stems develop cracks and over-callousing which lead to blockage of vascular bundles thereby affecting physiology causing stunted growth and sometimes die-back of the stems. It attacks only the young shoots which are the actual crop of tea (Rahman *et al.* 2005).

O. coffeae the red spider mite is another important major pest of tea. The larvae, nymphs and adults of *O. coffeae* cause damage to mature leaves of tea by sucking the sap to form flecks. Reddish spots develop on the sucking sites, which subsequently unite to form large brown patches. They are mostly confined to the mature foliage and prefer the upper surface of mature leaves. Spherical and reddish eggs are laid on the upper surface of mature leaves. This species occurs throughout the year in North-east India and its reproductive rate increases with temperature (Das 1965). Peaks in oviposition were observed at dawn and dusk (Banerjee and Das 1968). The age of bushes in the pruning cycle influences the abundance of

*Corresponding address:
entosomnath@yahoo.co.in; entosomnath@rediffmail.com

mites on tea. Incidence of *O. coffeae* on pruned tea is less than on unpruned or skiffed plants (Das 1960).

As a result of infestation by the both pests, plant growth, and leaf productivity are seriously affected. *H. theivora* and *O. coffeae* being polyphagous pests with high reproductive and damage potential, their suppression becomes inevitable. These pests had been causing a considerable damage in tea cultivation in India since 1960 but recently its havoc is more prominent in North Bengal tea plantation due to environmental changes (Mukhopadhyay and Roy 2009).

Chemical control would continue to be the first line of defense against these two pest particularly under outbreak situation. With increases in the quantity of pesticide being applied every passing year, the problem has been aggravated and the cost of pest control is increasing day by day (Sannigrahi and Talukdar 2003).

Control failures due to pesticide resistance against these two pests are now common and in this situation economic production of tea has become increasingly difficult (Gurusubramanian *et al.* 2008). One of the insecticide resistant management strategies is the use of chemicals that can effectively control the pest in the initial stage itself (egg stage). However most of the earlier studies were done to control the mobile stages of *H. theivora* and *O. coffeae*, but the present experiment was conducted to evaluate the effectiveness of acaricides/insecticides in killing its eggs.

MATERIALS AND METHODS

Maintenance of *H. theivora* and *O. coffeae* in laboratory

Adults and nymphs of *H. theivora* and *O. coffeae* were collected from tea fields of the North Bengal, India during the flushing seasons (2007–2008). The field collected *H. theivora* nymphs and adults were reared and maintained in the insect cage in the laboratory at 25±2°C and 70–80% RH on a susceptible tea clone, TV 1 by following the method of Bhuyan and Bhattacharyya (2006).

A culture of red spider mite was maintained in the laboratory at 25±2°C and 70–80% RH on a susceptible tea clone, TV 1 by the following detached leaf culture method of Helle and Sabelis (1985) with slight modifications.

Pesticides used in the study

Demineralised water solutions of tested pesticide of commercially available products (Table 1) were used in 5 to 8 selected concentrations, expressed in parts per million (ppm).

Table 1. List of pesticides tested, including trade name, class, active ingredient

Trade name	Class	Active substance	Manufacturer
For *Helopeltis theivora*			
Thiodan 35 EC	organochlorine	endosulfan 35%	Aventis Crop Science Ltd.
Asataf 75 SP	organophospates	acephate 75%	Rallis India Ltd.
Superban 20 EC	organophospates	chloropyriphos 20%	Trasco Super Agro India Ltd.
Rogor 30 EC	organophospates	dimethoate 30%	Rallis India Ltd.
Monocil 36 SL	organophospates	monocrotophos 36%	De-Nocil Crop Protection Ltd.
Metasystox 25 EC	organophospates	oxydemeton methyl 25%	Bayer India Ltd.
Curacron 50 EC	organophospates	profenofos 50%	Syngenta India Ltd.
Flash 25 EC	organophospates	quinalphos 25%	Indofil
Tata Alpha 10 EC	synthetic pyrethroids	alphamethrin 10%	Rallis India Ltd.
Bulldock 2.5 EC	synthetic pyrethroids	β-cyfluthrin 2.5%	Bayer India Ltd.
Cymbush 25 EC	synthetic pyrethroids	cypermethrin 25%	Syngenta India Ltd.
Decis 2.8 EC	synthetic pyrethroids	deltamethrin 2.8%	Bayer Crop Science Ltd.
Punkaso 10 EC	synthetic pyrethroids	etofenprox 10%	Rallis India Ltd.
Meothrin 30 EC	synthetic pyrethroids	fenpropathrin 30%	Sumitomo Chemical India Ltd.
Karate 5 EC	synthetic pyrethroids	λ-cyhalothrin 5%	Syngenta India Ltd.
Actara 25 WG	neonicotinoids	thiamethoxam 25%	Syngenta India Ltd.
Confidor 17.8 SL	neonicotinoids	imidacloprid 17.8%	Bayer India Ltd.
Neemazal-F	neem formulation	azadirachtin 5%	EID Parry India ltd.
For *Oligonychus coffeae*			
Klin XL 18.5 EC	organochlorine	dicofol 18.5%	Krishi Rasayan India Ltd.
Tafethion 50 EC	organophosphate	ethion 50%	Rallis India Ltd.
Curacron 50 EC	organophospates	profenofos 50%	Syngenta India Ltd.
Allmite 57 EC	organosulfite	propargite 57%	EID Parry India ltd.
Magister 10 EC	quinazoline	fenazaquin 10%	E.I.DuPont
Meothrin 30 EC	synthetic pyrethroids	fenpropathrin 30%	Sumitomo Chemical India Ltd.
Vertimac	antibiotics	abamectin 1.9%	Syngenta India Ltd.
Neemazal-F	neem formulation	azadirachtin 5%	EID Parry India ltd.

Collection of eggs from *H. theivora* and *O. coffeae*

Thirty gravid females of *H. theivora* were introduced on freshly collected TV 1 (commonly cultivated susceptible tea clone) shoots for egg laying and kept it for 12 hours inside the chimney. The next day the egg laden shoots were subjected to pretreatment count. 30 eggs were considered for each ovicidal treatment. Observations on per cent hatching and per cent mortality of neonate nymphs were recorded collectively up to 21 days. As Gope and Handique (1991) and Roy *et al.* (2009) suggested that maximum incubation period for *H. theivora* eggs lasted for 21 days in North East Indian agroclimatc condition. The eggs that did not hatch within this period were regarded as non-viable.

For assessment of ovicidal properties of acaricides, fifteen gravid females of *O. coffeae* were introduced on mature fourth leaf from the top of the shoot of TV 1 tea clone for oviposition and kept overnight in the Petri dish. These leaves were padded with water soaked cotton. After 24 hours the introduced mites were removed using a fine brush. The eggs laid on tea leaves were counted under microscope as pre-treatment count up to 30 eggs and tea leaves containing more than 30 eggs were removed cautiously by using fine needle. Observation were taken on the hatching of the eggs were made daily and continued up to 15 days, as in general eggs of *O. coffeae* hatched within that period (Das 1965).

Pesticide toxicity trial

After counting, (1-day-old eggs) of *H. theivora* and *O. coffeae* were exposed to graded concentrations of pesticides using glass atomizer at constant pressure of 2.5 kg/cm^2. Distilled water was sprayed on eggs kept as control. Observations were performed periodically after treatment along with control. Observations on per cent hatching and per cent mortality of neonate nymphs were recorded collectively up to 21 days in both cases. Those eggs that did not hatch after this period were regarded as non-viable.

A final assessment (ovicidal properties) was performed after 21 days of pesticide application and expressed as per cent mortality of the eggs at each dose, in relation to untreated control mortalities using Abbott's formula (Abbott 1925).

Mean lethal concentrations (LC_{50}) were calculated using computer program based on Finney probit analysis method (Finney 1973) and expressed in ppm of commercial pesticides solution.

Relative toxicity was determined based on LC_{50} values of a pesticide in reference to the corresponding lowest LC_{50} value of the pesticide (regarded as unit).

RESULTS

Comparison of the LC_{50} values of eighteen different insecticides for killing eggs of *H. theivora* (Table 2) showed the least susceptibility to endosulfan (3.5082 ppm) and the highest to etofenprox (0.0168 ppm). The order of susceptibility was: etofenprox > β-cyfluthrin ≥ cypermethrin > imidacloprid > fenpropathrin > λ- cyhalothrin > deltamethrin > profenofos > monocrotophos > thiomethoxam > alphamethrin > dimethoate > quinalphos > chlorpyriphos > oxydemeton methyl > acephate > azadirachtin > endosulfan (Table 2).

Table 2. Susceptibility level of *H. theivora* eggs to tested insecticides

Insecticide	n[a]	Slope ±SE	LC_{50} [%] and 95% FL[b] of LC_{50} (lower–upper)	X^2	df[c]	RT[d]
1	2	3	4	5	6	7
Endosulfan	240	0.5877±0.0067	3.5082 (2.0801–5.9169)	0.0027	6	1.00
Acephate	240	0.8783±0.0114	1.0134 (0.5125–2.0034)	0.0438	6	3.46
Chloropyriphos	240	1.8300±0.0030	0.1847 (0.1295–0.2633)	0.2955	6	18.99
Dimethoate	240	1.6844±0.0033	0.0929 (0.0642–0.1345)	0.0211	6	37.76
Monocrotophos	240	1.0285±0.0085	0.0429 (0.0237–0.0776)	0.0294	6	81.77
Oxydemeton methyl	240	0.9861±0.0095	0.5120 (0.2742–0.9560)	0.0921	6	6.85
Profenofos	240	0.5688±0.0256	0.0315 (0.0113–0.0876)	0.0173	6	111.37
Quinalphos	240	0.6120±0.0235	0.0949 (0.0356–0.2529)	0.0077	6	36.96
Alphamethrin	240	1.0870±0.0076	0.0730 (0.0417–0.1277)	0.00008	6	48.05
β- cyfluthrin	240	1.3731±0.0056	0.0228 (0.0141–0.0369)	0.1165	6	153.86
Cypermethrin	240	1.1282±0.0074	0.0228 (0.0131–0.0396)	0.0042	6	153.86

1	2	3	4	5	6	7
Deltamethrin 2.8% EC	240	2.0290±0.0032	0.0290 (0.0208–0.0430)	0.3303	6	117.33
Etofenprox 10% EC	240	1.1306±0.0068	0.0168 (0.0099–0.0286)	0.0251	6	208.82
Fenpropathrin	240	1.7431±0.0041	0.0247 (0.0164–0.0373)	0.2747	6	142.03
λ- cyhalothrin	240	1.6011±0.0043	0.0288 (0.0188–0.0439)	0.0757	6	121.81
Imidacloprid	240	0.5506±0.0262	0.0229 (0.0081–0.0644)	0.7179	6	153.19
Thiamethoxam	240	0.7122±0.0171	0.0479 (0.0207–0.1107)	0.0148	6	73.24
Azadirachtin 5%	240	0.7533±0.0123	2.0436 (1.0065–4.1496)	0.0536	6	1.71

[a] number of eggs tested; [b] fiducial limit; [c] degrees of freedom; [d] relative toxicity (RT) = LC_{50} of each pesticide/LC_{50} of endosulfan

Table 3. Susceptibility level of *O. coffeae* eggs to tested insecticides

Acaricide	n[a]	Slope ±SE	LC_{50} [%] and 95% FL[b] of LC_{50} (lower–upper)	X^2	df[c]	RT[d]
Ethion	720	1.3294±0.0054	0.2270 (2.0801–5.9169)	0.1147	6	9.40
Dicofol	720	0.2429±0.1259	0.9589 (0.0996–9.2327)	0.6613	6	2.22
Propargite	720	1.5432±0.0042	0.0433 (0.0286–0.0657)	0.0024	6	49.33
Fenazaquin	720	1.0257±0.0051	0.0037 (0.0024–0.0059)	0.3755	6	577.29
Fenpropathrin	720	1.7166±0.0032	0.0842 (0.0585–0.1212)	0.0001	6	25.36
Profenofos	720	0.8002±0.0135	0.0318 (0.0151–0.0669)	0.0041	6	67.16
Abamectin	720	0.7852±0.0132	1.1737 (0.5622–2.4503)	0.4361	6	1.81
Azadirachtin	720	0.6800±0.0139	2.1360 (1.0040–4.5443)	0.2123	6	1.00

[a] number of eggs tested; [d] fiducial limit; [c] degrees of freedom; [d] relative toxicity (RT) = LC_{50} of each pesticide/LC_{50} of azadirachtin

Among the insecticides tested, thiomethoxam, monocrotophos, profenofos, deltamethrin, λ-cyhalothrin, fenpropathrin, β-cyfluthrin, cypermethrin and etofenprox appeared to be 73.24–208.82 times more toxic than endosulfan (Table 2).

In case of *O. coffeae* the lowest LC_{50} value was determined for fenazaquin, which was followed by profenophos, propargite, fenpropathrin, ethion, dicofol, abamectin and finally by azadirachtin (Table 3). The values of relative toxicity when calculated taking LC_{50} of azadirachtin as unit showed that all the acaricides were more toxic than azadirachtin (Table 3). Based on relative toxicity derived on the basis of LC_{50} values, the highly toxic and most effective ovicidal acaricide was fenazaquin and was 577.29 times more toxic than azadirachtin followed by profenophos (67.16 times), propargite (49.33 times) and fenpropathrin (25.36 times) (Table 3). Chi-square values indicated a good fit of probit responses in all the bioassays showing that there was no heterogeneity between observed and expected responses.

DISCUSSION

Various workers reported that egg stage is the most vulnerable or susceptible stage to the insecticides having ovicidal action (Smith and Salkeld 1966; Singh *et al.* 1982). The present study indicates comparatively low ovicidal properties of insecticides against *H. theivora* eggs in comparision to other agricultural pests (Stoeva 1979; Ying 1982). Primarily due to their limited access of insecticides to eggs they largely remain protected being inserted in the plant tissue. Laboratory studies carried out in Central Asia, formerly USSR in 1979–1981 on spraying infested cotton leaves having eggs of *Helicoverpa armigera* showed that 3 days after treatment deltamethrin and fenvalerate caused 100 and 93.3% egg-mortality, respectively (Khodzhaev and Eshmatov 1983). Ovicidal toxicity of insecticides under laboratory conditions against *H. armigera* eggs were in descending order permethrin (89.9%), quinalphos (88.4%), monocrotophos (72.3%), phenthoate (55.6%), phosalone (29.0%) and chlorpyrifos (19.6%)

(Vekaria and Vyas 1985). Thus claiming superiority of the synthetic pyrethroid over organophosphates, is also evident in the present findings. Ahmed *et al.* (1990) reported high ovicidal activity of new generation pesticides against the eggs of *Heliothis armigera*. These view are also broadly supported by the present experiment. Watson *et al.* (1988) reported that egg mortality decreased with the increase of egg age.

Abamectin, dicofol, ethion and azadirachtin did not show a significant ovicidal action whereas fenazaquin showed the highest ovicidal effect on the eggs *O. coffeae*. The propargite showed intermediate level of ovicidal properties. Similar results were in accordance with Kumar and Singh (2004) who observed that abamectin, malathion, phosalone and azadirachtin were not showing the ovicidal action against *Tetranychus urticae* but propargite and dicofol at 0.025% concentration showed ovicidal effect on all the eggs. The earlier study on a relative toxicity of abamectin to *Phytoseiulus persimilis* and spider mite, *Tetranychus urticae* by Zhang and Sndorson (1990) reported that at a low concentration of abamectin it was not toxic to eggs of *T. urticae*.

There are controversies about correct interpretation of ovicidal effects of pesticides. Killing of eggs and larvae that comes out of joint treatment of eggs should give the right perspective for understanding of ovicidal action. For example, tetradifon or tedion show a strong ovicidal action because they affect eggs directly or indirectly. It is important that in some cases larvae die inside the chorion or egg-shell; and in other cases larvae die soon after hatching when they come in contact with the residual chemical deposits. A pesticide also sterilizes females. The eggs laid by such females may not be viable, in the sense that the larvae die soon after emergence. All these aspects should be considered in defining what ovicidal action is (Das 1983).

The present work evaluates the effectiveness of the commonly used insecticides/acaricides in killing eggs of *H. theivora* and *O. coffeae*. Perusal of data in this study suggests that these two pests even at egg stage have developed resistance/tolerance to various groups of pesticides. In this context, an Integrated Resistance Management (IRM) strategy seems to be most promising. The present day Integrated Pest Management (IPM) still relies heavily on chemicals intended for controlling the damaging stages (nymph and adult). However, under field conditions the observed control is a combination of the result of pesticide toxic action on all the stages. The contribution of ovicidal action to the total effect was well studied in *H. armigera* (Kathuria *et al.* 2000). In addition, regular updating of the strategy and tactics of *H. theivora* and *O. coffeae* management with the introduction of new concepts and approaches together with new insecticides (or ovicides) is required in order to have a better management of pests. To achieve this objective a clear understanding of factors affecting susceptibility of these pests to chemicals, mechanisms of action of different insecticides (or ovicides), their scope and limitations etc. is quite necessary so that these plant protection tools may be employed more efficiently. Therefore one of the IRM strategies shall be using ovicidal chemicals that can effectively control the pest in the initial stage itself.

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POLISH SUMMARY

WZGLĘDNA WRAŻLIWOŚĆ JAJ *HELOPELTIS THEIVORA* WATERHOUSE I *OLIGONYCHUS COFFEAE* NIETNER NA POWSZECHNIE STOSOWANE PESTYCYDY

Chrząszcz *Helopeltis theivora* Waterhouse i czerwony pajęczak *Oligonychus coffeae* Nietner, są dwoma głównymi szkodnikami herbaty (*Camellia sinensis* L.). Nasilenie ich występowania wzrasta z dnia na dzień w alarmującym tempie, a zwiększająca się odporność na pestycydy stanowi poważny problem na plantacjach herbaty w północnym Bengalu w Indiach. Jedną ze strategii zapobiegania wytwarzaniu się odporności na pestycydy jest stosowanie środków chemicznych mogących skutecznie zwalczać szkodnika w początkowym stadium rozwoju (jaja). Większość dotychczasowych badań dotyczyła eliminowania ruchliwych stadiów *H. theivora* i *O. coffeae*. Eksperyment przeprowadzono w celu oceny skuteczności akarycydów i insektycydów w niszczeniu jaj. Na podstawie wartości LC_{50} ustalono następującą, malejąca kolejność skuteczności różnych, powszechnie stosowanych insektycydów w zabijaniu jaj *H. theivora*: etofenprox, β-cyfluthrin, cypermethrin, imipdacloprid, fenpropathrin, λ-cyhalothrin, deltamethrin, profenofos, monocrotophos, thiomethoxam, alphametrin, dimethoate, quinalphos, chlorphyriphos, oxydemeton metyl, acephate, azadirachtin i endosulfan. W przypadku *O. coffeae* najniższą wartość LC_{50} ustalono dla fenazaquinu, a następnie dla związków: profenophos, propargite, fenpropathrin, ethion, dicofol, abamectin oraz azadirachtin. Wyniki badań mogą być wykorzystane jako element integrowanych programów roślin, mogących skutecznie zwalczać szkodniki w początkowym stadium ich rozwoju.