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Sensitivity of the Tea Mosquito Bug (*Helopeltis theivora* Waterhouse), to Commonly Used Insecticides in 2007 in Dooars Tea Plantations, India and Implication for Control

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Abstract: The tea mosquito bug (*Helopeltis theivora* Waterhouse) is one of the most serious pests in tea cultivations in India and insecticides continue to be an important tool for managing the pest. Constant and strong selective pressure of different insecticides used to control, has resulted in resistance of *H. theivora* to many insecticides. In connection with this situation, constant monitoring of *H. theivora* susceptibility level to all recommended insecticides is necessary. The objective of the study was to determine the effectiveness of commonly used insecticides, most often used in the Dooars tea plantation of North Bengal, India for *H. theivora* control. The study indicated that relative susceptibility values (LC_{50}) of *H. theivora* to different insecticides varied region wise. The populations of Kalchini tea subdistrict showed less susceptibility to all insecticides tested as compared to the high susceptibility of those from the Damdim and Chulsa subdistricts to most of the tested insecticides. The populations of the Nagrakata, Dalgong and Binnaguri subdistrict represented intermediate level of susceptibility to different insecticides tested. The LC_{95} values of the experiments when compared with the recommended dosages, it suggested medium to high resistance coefficient values was recorded in endosulfan, low to medium resistance coefficient for cypermethrin, lamda cyhalothrin, imidacloprid and quinalphos. However, there was not much change in case of other registered insecticides, which therefore was found effective at recommended dose.

Key words: *Helopeltis theivora* · Tea mosquito bug · Insecticide resistance · Pyrethroids · Organophosphates · Neonicotinoids · Tea · Plant protection

INTRODUCTION

The tea mosquito bug, *Helopeltis theivora* Waterhouse is an important pest of the tea (*Camellia sinensis*) plantation causing substantial (10-50%) crop loss in India. Among the tea growing region of India, pest activity has always been reported to be high in the Dooars [1, 2]. In the Dooars tea plantation, 80% of plantations have been suffering from *H. theivora* infestation. This insect pest has been exposed mainly to organochlorine, pyrethroids and organophosphorus insecticides for many years and lately to neonicotinoid insecticides. Recently, *H. theivora* populations resistant to commonly used insecticides were found in some parts of India, such as Assam [3, 4], Dooars [5] and Darjeeling [6].

In connection with the information concerning the lack of effectiveness of numerous synthetic insecticides in *H. theivora* control, the University of North Bengal at Darjeeling District in West Bengal, India started monitoring susceptibility level of *H. theivora* to active substances of the commonly used chemical groups (organochlorine, organophosphates, pyrethroids and neonicotinoids). Nowadays, constant monitoring of *H. theivora* susceptibility to insecticides is essential for working out insecticide resistance management strategies, necessary for maintaining the effectiveness of chemical control.

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MATERIALS AND METHODS

In 2007 tea mosquito bugs were collected for testing from 6 distant fields representing populations occurring in the Dooars region (North Bengal, India): Damdim, Chulsa, Nagrakata, Binnaguri, Dalgong and Kalchini. A culture of *H. theivora* was maintained in the laboratory at 27±2°C, 70-80% RH and a 16:10 LD photoperiod for three days on a susceptible tea clone, TV1 by following hurricane-lamp glass chimneys method of Gope and Handique [7] with slight modifications.

Insecticides used in the studies were imidaclopyrid 17.5 SL, thiomethoxam 25 WG, deltamethrin 2.8 EC, alphamethrin 10 EC, cypermethrin 25EC, λ-cyhalothrin 5 EC, fenpropathrin 30 EC, monocrotophos 37SL, endosulfan 35 EC, quinalphos 25 EC, profenophos 50 EC and oxydemeton methyl 25 EC. In laboratory tests, a standard method recommended by Insecticide Resistance Action Committee (IRAC method No. 7) was used. Demineralised water solutions of tested insecticides of commercially available products were used in 5 to 8 selected concentrations, expressed in parts per million (ppm). The initial concentrations were different, depending on a particular insecticide. They were determined on the base of concentrations causing insect mortality above 50% and below 100%. Fifteen tea shoots for each treatment were dipped up-to five seconds in graded concentrations of each selected insecticide solution to ensure complete welting and then they were kept in a glass tube containing water and wrapped with cotton. Control tea shoots were dipped in demineralised water. Untreated and treated tea shoots were kept under ceiling fans for 15 minutes to evaporate the emulsion. The glass tubes containing tea shoots were placed in glass chimneys (20cm x 15 cm). Muslin cloth was tied with the help of rubber bands on top of the glass chimneys for ensuring a good evaporation and ventilation. The chimneys were kept at 27 ± 2°C in culture room. Thirty field collected and preconditioned *H. theivora* were released into each glass chimney. Each concentration comprised of three replications and the control. It was aimed at ensuring a frequent contact of plants with the insects. Thirty numbers of *H. theivora* were placed in each jar. The jars were closed with airy material for ensuring a good evaporation and ventilation. Each concentration comprised of three replications and the control. A final assessment (lethal effects of the active substances of insecticides) was determined after 48 hours of insecticide application and expressed as per cent mortality of insects at each dose, in relation to untreated control mortalities using Abbott's formula [8] if needed (mortality above 10%). At each assessment, *H. theivora* were classified as either: (a) unaffected, giving a normal response (such as taking a coordinated step, able to fly) (b) dead or affected, giving an abnormal response to stimulation. Lethal concentrations (LC_{50} and LC_{95}) were calculated using computer program based on Finney probit analysis method [9] and expressed in ppm of commercial insecticides solution.

To assess the resistance of a given population of tea mosquito bugs, the resistance coefficient was calculated as follows [10]:

Resistance coefficient (RC) = LC_{95}/recommended field dose

The following criteria for resistance assessment were assumed:

RC = 1-the lack of resistance
RC = 1.1-2-low resistance
RC = 2.1-5-medium resistance
RC = 5.1-10-high resistance
RC > 10-very high resistance

RESULTS

Relative Toxicity of Different Classes of Insecticides Against *H. Theivora*: Research results (Tables 1-6) showed change in susceptibility of *Helopeltis theivora* collected from six distant fields (sub district) in the Dooars region to different classes of insecticides.

Organo Chlorine: The Kalchini population recorded a maximum LC_{50} value to endosulfan (1580.77 ppm) followed by population from Dalgong (952.72 ppm), Binnaguri (938.21 ppm), Nagrakata (884.95 ppm) and Damdim (544.72 ppm). Lowest LC_{50} value was observed in population from Chulsa (269.74 ppm).

Organophosphates: Dalgong population recorded a maximum LC_{50} value to monocrotophos (18.05 ppm) followed by population from Nagrakata (17.90 ppm), Kalchini (16.27 ppm), Chulsa (7.38 ppm) and Binnaguri (4.59 ppm). Lowest LC_{50} value was observed in population from Damdim (3.03 ppm).

Table 1: Susceptibility level of *H. theivora* of Damdim population to tested insecticides, expressed as LC_{50}, LC_{95} and resistance coefficient (LC_{95}/recommended field dose)

Chemical group	Active substance	Recommended dose [ppm]	LC_{50} [ppm] (confidence interval, p = 0.95)	LC_{95} [ppm]	Resistance coefficient (LC_{95}/recommended dose)
Organo chlorine	Endosulfan 35 EC	350	544.72 (607.75-480.32)	1446.70	4.13
Organophosphates	Quinalphos 25 EC	250	18.34 (21.14-15.90)	64.03	0.26
	Profenfos 50 EC	200	12.33 (13.97-10.88)	32.17	0.16
	Oxydemeton methyl 25 EC	250	18.31 (19.57-17.13)	31.35	0.13
	Monocrotophos 37 SL	370	3.025 (3.38-2.71)	7.96	0.02
Neonicotinoids	Imidacloprid 17.8 SL	23.50	10.16 (11.31-9.13)	26.16	1.11
	Thiomethoxam 25 WG	50	4.60 (5.63-3.76)	25.10	0.50
Pyrrthroids	Deltamethrin 2.8 EC	5.6	0.29 (0.35-0.24)	1.29	0.23
	Cypermethrin 10 EC	10	1.28 (1.58-1.03)	5.82	0.58
	Alphamethrin 10 EC	10	0.23 (0.85-0.71)	1.55	0.16
	Lamda cyhalothrin 5 EC	10	0.56 (0.65-0.49)	1.79	0.18
	Fenpropathrin 30 EC	75	0.03 (0.05-0.02)	1.44	0.02

Table 2: Susceptibility level of *H. theivora* of Chulsa population to tested insecticides, expressed as LC_{50}, LC_{95} and resistance coefficient (LC_{95}/recommended field dose)

Chemical group	Active substance	Recommended dose [ppm]	LC_{50} [ppm] (confidence interval, p = 0.95)	LC_{95} [ppm]	Resistance coefficient (LC_{95}/recommended dose)
Organo chlorine	Endosulfan 35 EC	350	269.74 (328.18-221.71)	1940.60	5.54
Organophosphates	Quinalphos 25 EC	250	6.56 (7.94-5.42)	35.24	0.14
	Profenfos 50 EC	200	7.63 (8.65-6.73)	19.76	0.10
	Oxydemeton methyl 25 EC	250	19.36 (20.74-18.08)	33.87	0.14
	Monocrotophos 37 SL	370	7.38 (7.89-6.89)	12.69	0.03
Neonicotinoids	Imidacloprid 17.8 SL	23.50	15.05 (16.51-13.72)	31.42	1.34
	Thiomethoxam 25 WG	50	4.74 (5.92-3.79)	29.42	0.59
Pyrrthroids	Deltamethrin 2.8 EC	5.6	0.13 (0.16-0.11)	0.72	0.13
	Cypermethrin 10 EC	10	0.80 (0.97-0.67)	3.38	0.34
	Alphamethrin 10 EC	10	0.29 (0.33-0.25)	0.88	0.09
	Lamda cyhalothrin 5 EC	10	0.47 (0.53-0.42)	1.22	0.12
	Fenpropathrin 30 EC	75	0.04 (0.07-0.03)	2.25	0.03

Table 3: Susceptibility level of *H. theivora* of Nagrakata population to tested insecticides, expressed as LC_{50}, LC_{95} and resistance coefficient (LC_{95}/recommended field dose)

Chemical group	Active substance	Recommended dose [ppm]	LC_{50} [ppm] (confidence interval, p = 0.95)	LC_{95} [ppm]	Resistance coefficient (LC_{95}/recommended dose)
Organo chlorine	Endosulfan 35 EC	350	884.95 (988.90-791.94)	2160.51	6.17
Organophosphates	Quinalphos 25 EC	250	38.84 (44.01-34.27)	112.59	0.45
	Profenfos 50 EC	200	11.79 (12.86-10.81)	24.00	0.12
	Oxydemeton methyl 25 EC	250	30.99 (37.97-25.30)	186.76	0.75
	Monocrotophos 37 SL	370	17.90 (20.17-15.89)	44.08	0.12
Neonicotinoids	Imidacloprid 17.8 SL	23.50	15.54 (16.99-14.20)	32.40	1.38
	Thiomethoxam 25 WG	50	5.76 (6.99-4.74)	31.43	0.63
Pyrrthroids	Deltamethrin 2.8 EC	5.6	0.691 (0.77-0.62)	1.77	0.32
	Cypermethrin 10 EC	10	3.81 (4.79-3.03)	26.39	2.64
	Alphamethrin 10 EC	10	0.76 (0.81-0.71)	1.31	0.13
	Lamda cyhalothrin 5 EC	10	3.175 (3.95-2.56)	20.61	2.06
	Fenpropathrin 30 EC	75	0.05 (0.08-0.03)	4.88	0.07

Table 4: Susceptibility level of *H. theivora* of Binnaguri population to tested insecticides, expressed as LC_{50}, LC_{95} and resistance coefficient (LC_{95}/recommended field dose)

Chemical group	Active substance	Recommended dose [ppm]	LC_{50} [ppm] (confidence interval, p = 0.95)	LC_{95} [ppm]	Resistance coefficient (LC_{95}/recommended dose)
Organo chlorine	Endosulfan 35 EC	350	938.21 (1017.63-864.99)	1848.5	5.28
Organophosphates	Quinalphos 25 EC	250	43.76 (49.93-38.36)	91.19	0.36
	Profenfos 50 EC	200	11.24 (12.22-10.33)	20.90	0.10
	Oxydemeton methyl 25 EC	250	30.05 (35.21-25.65)	58.23	0.23
	Monocrotophos 37 SL	370	4.59 (6.10-3.46)	41.96	0.11
Neonicotinoids	Imidacloprid 17.8 SL	23.50	18.50 (19.74-17.33)	31.01	1.32
	Thiomethoxam 25 WG	50	5.56 (7.14-4.33)	42.07	0.84
Pyrrthroids	Deltamethrin 2.8 EC	5.6	0.33 (0.43-0.25)	2.80	0.50
	Cypermethrin 10 EC	10	2.22 (2.74-1.81)	41.73	4.17
	Alphamethrin 10 EC	10	0.59 (0.70-0.50)	2.22	0.22
	Lamda cyhalothrin 5 EC	10	1.33 (1.60-1.11)	16.59	1.66
	Fenpropathrin 30 EC	75	0.04 (0.07-0.02)	3.73	0.05

Table 5: Susceptibility level of *H. theivora* of Dalgong population to tested insecticides, expressed as LC_{50}, LC_{95} and resistance coefficient (LC_{95}/recommended field dose)

Chemical group	Active substance	Recommended dose [ppm]	LC_{50} [ppm] (confidence interval, p = 0.95)	LC_{95} [ppm]	Resistance coefficient (LC_{95}/recommended dose)
Organo chlorine	Endosulfan 35 EC	350	952.72 (1099.37-825.69)	2829.97	8.09
Organophosphates	Quinalphos 25 EC	250	29.05 (33.75-25.00)	106.86	0.43
	Profenfos 50 EC	200	12.11 (13.76-10.66)	32.97	0.16
	Oxydemeton methyl 25 EC	250	58.35 (66.36-51.30)	200.83	0.80
	Monocrotophos 37 SL	370	18.05 (20.42-15.95)	47.06	0.13
Neonicotinoids	Imidacloprid 17.8 SL	23.50	15.17 (17.65-13.04)	55.13	2.35
	Thiomethoxam 25 WG	50	5.35 (6.83-4.18)	38.09	0.76
Pyrrthroids	Deltamethrin 2.8 EC	5.6	0.68 (0.76-0.61)	1.64	0.29
	Cypermethrin 10 EC	10	3.03 (3.71-2.47)	15.13	1.51
	Alphamethrin 10 EC	10	0.44 (0.50-0.38)	1.33	0.13
	Lamda cyhalothrin 5 EC	10	2.41 (2.95-1.96)	14.41	1.44
	Fenpropathrin 30 EC	75	0.06 (0.09-0.04)	2.24	0.03

Table 6: Susceptibility level of *H. theivora* of Kalchini population to tested insecticides, expressed as LC_{50}, LC_{95} and resistance coefficient (LC_{95}/recommended field dose)

Chemical group	Active substance	Recommended dose [ppm]	LC_{50} [ppm] (confidence interval, p = 0.95)	LC_{95} [ppm]	Resistance coefficient (LC_{95}/recommended dose)
Organo chlorine	Endosulfan 35 EC	350	1580.77 (1756.22-1422.48)	3737.95	10.68
Organophosphates	Quinalphos 25 EC	250	214.47 (254.54-180.71)	948.20	3.79
	Profenfos 50 EC	200	29.71 (33.97-25.99)	86.46	0.43
	Oxydemeton methyl 25 EC	250	74.08 (82.08-66.85)	193.56	0.77
	Monocrotophos 37 SL	370	16.27 (20.05-12.06)	108.96	0.29
Neonicotinoids	Imidacloprid 17.8 SL	23.50	19.91 (22.50-17.62)	56.70	2.41
	Thiomethoxam 25 WG	50	5.74 (7.28-4.52)	37.45	0.75
Pyrrthroids	Deltamethrin 2.8 EC	5.6	0.73 (0.82-0.68)	4.50	0.80
	Cypermethrin 10 EC	10	7.48 (8.76-6.38)	27.88	2.79
	Alphamethrin 10 EC	10	1.53 (1.67-1.40)	3.42	0.34
	Lamda cyhalothrin 5 EC	10	5.32 (6.44-4.40)	25.32	2.53
	Fenpropathrin 30 EC	75	0.06 (0.11-0.04)	7.79	0.10

The Kalchini population recorded a maximum LC_{50} value to profenfos 50 EC (29.71 ppm) followed by population from Damdim (12.33 ppm), Dalgong (12.11 ppm), Nagrakata (11.79 ppm) and Binnaguri (11.24 ppm). Lowest LC_{50} value was observed in population from Chulsa (7.63 ppm).

On the basis of LC_{50} values, the descending order of toxicity of quinalphos 25 EC was observed in six different subdistricts in the Dooars was Chulsa (6.56 ppm), Damdim (18.34 ppm), Dalgong (29.05 ppm), Nagrakata (38.84 ppm), Binnaguri (43.76 ppm) and Kalchini (214.47 ppm).

Population of *H. theivora* collected from Kalchini sub-district was comparatively less susceptible to oxydemeton methyl 25 EC which registered LC_{50} value of 74.08 whereas the Damdim population showed relatively higher degree of susceptibility to the same insecticides. Considering the LC_{50} values of oxydemeton methyl 25 EC, the order of susceptibility was as: Damdim (18.31 ppm) > Chulsa (19.36 ppm) > Binnaguri (30.05 ppm) > Nagrakata (30.99 ppm) > Dalgong (58.35 ppm) > Kalchini (74.08 ppm).

Neonicotinoids: Kalchini population recorded a maximum LC_{50} value to imidacloprid 17.8 SL (19.91 ppm) followed by population from Binnaguri (18.50 ppm), Nagrakata (15.54 ppm), Dalgong (15.17 ppm), Chulsa (15.05 ppm) and Lowest LC_{50} value was observed in population from Damdim (10.16 ppm).

Populations from Kalchini, Nagrakata, Binnaguri and Dalgong showed more or less same LC_{50} values against thiomethoxam 25 WG that ranged from 5.35 to 5.76 but Damdim and Chulsa showed relatively lower LC_{50} i.e. 4.59 ppm and 4.74 ppm respectively.

Pyrrthroids: On the basis of LC_{50} values (Table 8), the descending order of toxicity of deltamethrin 2.8 EC to *H. theivora* in six different subdistricts in the Dooars was: Chulsa (0.13 ppm), Damdim (0.29 ppm), Binnaguri (0.33 ppm), Dalgong (0.68 ppm), Nagrakata (0.69 ppm) and Kalchini (0.73 ppm).

Kalchini population recorded a maximum LC_{50} value for cypermethrin 10 EC (7.46 ppm) followed by population from Nagrakata (3.81 ppm), Dalgong (3.03 ppm), Binnaguri (2.22 ppm), Damdim (1.28 ppm) and the lowest LC_{50} value was observed in population from Chulsa (0.80 ppm).

Kalchini population recorded a maximum LC_{50} value for alphamethrin 10 EC (1.53 ppm) followed by population from Nagrakata (0.76 ppm), Binnaguri (0.59 ppm), Dalgong (0.44 ppm) and Chulsa (0.29 ppm).

Kalchini population recorded a maximum LC_{50} value for lamda cyhalothrin 5 EC (5.32 ppm) followed by population from Nagrakata (3.17 ppm), Dalgong (2.41 ppm), Binnaguri (1.34 ppm), Damdim (0.56 ppm) and the lowest LC_{50} value was observed in population from Chulsa (0.47 ppm).

Populations from Damdim, Chulsa, Nagrakata and Binnaguri showed close LC_{50} values against fenpropathrin that ranged from 0.03 to 0.05 ppm but Kalchini and Dalgong showed slightly higher LC_{50} i.e. 0.06 ppm.

The data on dosage-mortality response of *H. theivora* collected from different subdistricts in the Dooars revealed that probit responses in all the bioassays were good fit, thus showing no heterogeneity between observed and expected responses.

Resistance of *Helopeltis theivora* to Different Insecticides in the Dooars Tea Plantation: Research results (Tables 1-6) showed, LC_{95} values calculated for endosulfan 35 EC exceeded recommended doses in all cases. There were significant differences [from 4.13 (Damdim) to 10.68 (Kalchini)] among resistance coefficient values of endosulfan. Resistance of *H. theivora* to endosulfan was medium in one case (Damdim), high in four cases (Chulsa, Nagrakata, Binnaguri, Dalgong) and very high resistance i.e. 10.68 in the remaining one case (Kalchini). Therefore endosulfan demonstrated the worst action against *H. theivora* in the experiments.

The resistance coefficient calculated for Cypermethrin 10 EC indicated low resistance of *H. theivora* in one case (Dalgong) and medium resistance also in three cases (Nagrakata, Binnaguri, Kalchini).

The resistance coefficient for imidacloprid 17.8 SL showed medium resistance in two cases (Kalchini, Dalgong) and low resistance in three cases (Binnaguri, Nagrakata, Chulsa, Damdim).

Resistance coefficient value of 3.79 (i.e. medium resistance) was only recorded in Kalchini population and rest of the populations were include in the lack of resistance categories.

As no major development of resistance for monocrotophos 37SL, Profenfos 50 EC, Oxydemeton methyl 25 EC, Thiomethoxam 25 WG, Deltamethrin 2.8 EC, Alphamethrin 10 EC, Fenpropathrin 30 EC ($RC \leq 1$-the lack of resistance) were evident, these insecticides therefore hold promise to be used effectively even at a lower one than the recommended dose.

DISCUSSION

The present study suggested that the populations of Kalchini tea subdistrict showed less susceptibility to all insecticides tested as compared to the high susceptibility of those from the Damdim and Chulsa subdistricts to most of the tested insecticides. The populations of the Nagrakata, Dalgong and Binnaguri subdistrict represented intermediate level of susceptibility to different insecticides tested. The LC_{50} values of the insecticides against *H. theivora* were in general low in the less pesticide-applied areas of Chulsa and Damdim as compared to other locations [11]. Kalchini subdistrict (high pesticide applied area) registered highest LC_{50} value for almost all tested insecticides. This differential response to the insecticides in the populations of the Dooars could be due to indiscriminate use of insecticides.

A comparison of LC_{50} values of most insecticides used against *H. theivora* population of the Dooars with other tea growing part of the North East India (Darjeeling and Assam) revealed that the insecticides are proving to be 2 to 350 times less toxic to the Dooars populations than those of other regions [4, 6]. *H. theivora* showed lowest susceptibility to endosulfan in all tea growing subdistricts of the Dooars with high LC_{50} value ranging from 269.744 ppm to 1580.77 ppm (For all numbers you must refer to the numbers in Table. 1-6). The poor performance of endosulfan against *H. theivora* has been reported by Roy *et al.* [5, 12]. The present study suggest that usual recommended dose of organochlorines (endosulfan: in all subdistricts), synthetic pyrethroids (cypermethrin and λ-cyhalothrin: in four subdistricts viz. Kalchini, Dalgong, Nagrakata and Binnaguri), neonicotinoids (imidacloprid: in all subdistricts) and organophosphates (quinalphos: in Kalchini subdistrict) were practically ineffective against *H. theivora* population. The change towards less susceptibility of *H. theivora* against endosulfan was found to be remarkable. Similar findings were reported against *H. theivora* population from Jorhat tea plantations of South Assam, India [13]. According to Borbora and Biswas [1] and Sannigrahi and Talukdar [2] organochlorines (endosulfan), synthetic pyrethroids (cypermethrin) and organophosphates (quinalphos) were extensively used for tea pest management in the Dooars for a long period of time whereas molecules like imidacloprid and λ-cyhalothrin were introduced in tea very recently. Such high levels of resistance to these compounds may be mediated through different mechanisms. Mechanisms of insecticides resistance in pest include reduced penetration [14, 15], decreased nerve sensitivity and enhanced metabolism [16], besides behavioral adaptations of feeding, oviposition and avoidance of pesticide surface contract. The absence of a common resistance mechanism that could confer cross-resistance between these compounds suggests that the use of the compounds in rotations or sequences for resistance management should be explored. However, there was no major change in susceptibility for monocrotophos, profenfos and fenpropathrin, which therefore may prove effective, even at a lower dose than the recommended ones.

There is a great deal of variation of *H. theivora* resistance to insecticide from location to location within Dooars tea ecosystems. Such variation in different geographical populations of pests has also been reported by Kranthi *et al.* [17], Chaturvedi [18] and Fakrudin *et al.* [19] in Cotton Bollworm, (*Helicoverpa armigera*) from Central and South Indian Cotton ecosystem and from Northern China with same pest [20].

The resistance levels in Kalchini, Dalgong, Binnaguri and Nagrakata region are high possibly due to heavy dependence on insecticides. The synthetic pyrethroids are being used widely in tea plantations and their consumption is about 3-5 liters/ha in North East India [21] and recent survey in the present study 2008 revealed that on an average 7.499 liter of insecticides was used per hectare per year in Dooars of which the organo-chlorine, organophosphate and carbamate (non-pyrethroid) accounted 73.5% and pyrethroid represent 36.6% during 1998 to 2004. Endosulfan, quinalphos and cypermethrin were extensively used in all the regions of the Dooars and it was noted that the requirement of synthetic pyrethroid gradually increased with every passing year in all subdistricts. This trend was due to the reason that: i) per hectare requirement of synthetic pyrethroid was less (100 ml/ha), ii) These are attractive due to knockdown effect and also iii) cost effectiveness. Against the tea mosquito bug most planters used insecticide spray as prophylaxic. As the occurrence wet monsoon season (May-July) coincided consumption of pesticides also increased, resulting in about 8-16 applications per year of synthetic pyrethroids on top of other chemical applications.

The study conducted by Forrester [22] also clearly revealed that resistance levels increased when pyrethroids were used but fell significantly when they were withheld. Thus the pesticides were exerting a high selection pressure to resistant genotypes, clearly explaining why resistance levels were proportionate with the usage of pesticides. This suggests that indiscriminate use and heavy dependence on pesticide will further complicate the already worsened situation and these hint at introduction of a comprehensive insecticide resistance management strategy.

Resistant management strategies appropriate for the region should be included:-(1) greater control over insecticide application and use. Unless this happens, the areas affected by resistant *H. theivora* populations will continue to increase and could ultimately result in the abandonment of tea growing in large areas of Northeast India. (2) Dilution of the allelic frequencies for major insecticide resistance genes by allowing susceptible *H. theivora* population to exist in refugia.

(3) Restricted use of endosulfan, cypermethrin, imidacloprid, quinalphos and λ-cyhalothrin since their effective dose was higher than the recommended dose, in *H. theivora* prone areas and reviewing of the recommended dose (4) Judicious use of these insecticides only if their use is essential, (5) No prophylactic spraying of chemicals, (6) Timing and frequency of applications should be such which does not create selection pressure and (7) altering of the insecticides in such a way that their mode of action are different. (8) Biotypes identification through molecular techniques besides the log dose probit assays.

This has to be tested on experimental basis before embarking. Till date there has been little study on the patterns of mobility of *H. theivora* and a comprehensive study on the alternate host. It will be more meaningful if population fingerprints for all the six geographic populations of *H. theivora* from the Dooars tea ecosystem. Can be done, which may pinpointing precise population fluxing patterns over time and space. Outcome of such efforts should be integrated with results reported in this study for contigent planning to mitigate the problem of insecticide resistance.

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