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- Records and evidences of population change of *Helopeltis theivora* in the sub-Himalayan Dooars region during last 24 years (1980-2004) indicated that *H. theivora* infestation was low during 1980 to 1990. After that, the severity of the infestation of *H. theivora* in the Dooars region had increased from year to year. An outbreak of *H. theivora* had occurred more frequently causing severe damage of tea plantation in the Dooars since the year 1997. During the years 2000 to 2004 it was noted that 70 to 83% of tea estates in the Dooars suffered from moderate to severe *H. theivora* infestation. By and large the subdistricts of Kalchini, Dalgong, Nagrakata and Binnaguri suffered severe damage by this pest. The rest subdistricts of the Dooars such as Chulsa and Damdim showed low incidence pattern of *H. theivora.* The study also earmarked that Kalchini subdistrict as a high *Helopeltis* prone zone in the Dooars tea plantation.
- The survey which was conducted to determined the insecticide use patterns in the tea plantations of the Dooars during the period 1998 to 2004 revealed that on an average 7.499 kg/l of insecticides was used per hectare per year of which the organochlorine, organophosphate and carbamate (Non-pyrethroid) accounted 73.5% and pyrethroid for 36.6%. Among the different Sub Districts of the Dooars, lowest consumption was noted in Damdim subdistrict (5.799 kg/I per hectare) followed by Chulsa (6.433 kg/I per hectare), Binnaguri (7.399 kg/I per hectare), Nagrakata (7.655 kg/I per hectare), Dalgong (7. 920 kg/I per hectare), and finally

highest consumption was noted in Kalchini (9.793 kg/I per hectare). The requirement of synthetic pyrethroid gradually increased with every passing year in all subdistricts of the Dooars. Endosulfan, monocrotophos, deltamethrin and cypermethrin were extensively used in all the regions of the Dooars.

- The population of *H. theivora* was abundant throughout the year in the Dooars. Incidence of *H. theivora* was at the lowest number in December to February. The population usually began to build up in the months of May/June and reaching a peak during September to November. Simple regression between population of *H. theivora* and different weather factors in the Dooars suggested that rainfall had a significant negative influence. Both maximum and minimum temperatures and sunshine hours had significant positive influence on *H. theivora* population. In case of relative humidity a positive of influence was observed in the morning and which in the afternoon hours showed negative correlation with *H. theivora* population but the influence of relative humidity in the afternoon was not found statistically significant. In spite of these, other additional factors appeared to influence the population incidence of *H. theivora* resulting in low R^2 value in multiple regression equation.
- The development time of the stages of *H. theivora* varied widely in different months of the year. The lowest duration of incubation period was noticed during September and October. The development period varied from 8.4 to 16.2 days. During May to October nymphal development was

completed within a short time, while it was longest in the month of January. No significant difference was observed in hatchability, survival during post embryonic development and pre oviposition period in different seasons of the year. The total number of eggs laid by a female was as high as 136.6 ± 18.68 in the month of September and as low as 73 to 74.2 during January - February. During October and November high rate of egg laying, in the tune of 127.0 ± 17.50 and 114.8 ± 8.25 eggs per female respectively was recorded. During rest months of the year the fecundity per female was recorded between 75 and 90. Female bug survived for a longer period than the male. The longevity of female varied significantly in different months of the year. Longevity of female had positive correlation with their oviposition period.

- Comparative study on life cycle traits of *H. theivora* on tea and a much-preferred alternate host, *Mikania micrantha* (common climbing weed in the Dooars tea plantation) suggested that there was no significant difference in the egg incubation period, sex ratio of female to male and male longevity. But rest of the biological parameters i.e. hatchability (% of egg hatched), total nymphal duration, percent of nymphs reaching to adult stage, pre oviposition period, oviposition period, fecundity and female longevity varied significantly. The egg hatchability of *H. theivora* on *M. micrantha* was 25 – 30% lower than that on tea and the total nymphal duration and total developmental period of the bug on *M. micrantha* was significantly longer than that on tea. Significant reduction in percent of

nymphs reaching adult stage was noted in *M. micrantha* in comparison with tea. There was 73.35% reduction in the fecundity of *H. theivora* on *M. micrantha* when compared to that on tea. The prolongation of pre-oviposition and oviposition periods of *H.theivora* on *M. micrantha* was 1.77 and 3.28 folds more than that on tea (*Camellia sinensis*).

- Number of lesions in the form of "fluid-soaked feeding spots" on the upper surface of tea leaves **produced by** nymphs and adults **per day** were in the order of: - female (104.57)> 2nd instar (88.29)> 3rd instar (80.21)> 4th instar (68.87)> 1st instar (66.66)> male (65.72)> 5th instar (60.24). But on the basis of **total feeding spots** made during different stages these were in the order of female (4682.2) > male (1407.0) > 3rd instar (287.8) > 2nd instar (270.8) > 1st instar (186.6) > 4th instar (180.6) > 5th instar (90.35). There was a direct correlation between the age of the instar and diameter of the feeding puncture. The diameter of the spot of female was significantly larger than those made by male. The 2nd leaf was the most preferred site by the third and fourth instars and adults. On the other hand, the first and second instars preferred the 1st leaf.
- Amongst the 28 tea cultivars screened TV1, TV12, TV23, TS653 and TV16 were the most susceptible to *H.theivora* infestation. TV4, TV11, TV28, TV29 and ST449 were less susceptible and TV2, TV9, TV17, TV18, TV20, TV25, TV26, TV30, Teenali 17, TS652, TS491, P126, TV7, TV10, TV14, TV19, TV22, and TS426 were moderately susceptible. No clone was immune to infestation by *H. theivora.*

- The thirty-eight plants (weed to tree), commonly available in the Dooars tea plantation and its adjoining areas were screened for ascertaining their status as alternate hosts of *H.theivora*. Among them Mikania (*Mikania micrantha*), Guava (*Psidium guajava*), *Acaphyla* sp., Melastoma (*Melastoma* sp.), Dayflower (*Commelina* spp.), Oak (*Quercus* spp.), Rai (*Brassica juncea*), Jackfruit (*Artocarpus heterophylla*), *Acacia moniliformis*, Thoroughwort (*Eupatorium* sp.), Jamun (*Eugenia jambolana*), fragrant thoroughwort (*Eupatorium odoratum*), Bortengeshi (*Oxalis acetocello*), *Premna latifolia*, Boal (*Ehretia acuminata*), Sesbania (*Sesbania cannibina*) and Ornamental jasmine (*Gardenia jesminoid*) showed "fluid-soaked" spots caused by feeding of *H. theivora* in no choice situation. The binary choice test experiment with tea and the alternate host suggested that *H. theivora* clearly preferred tea plants, followed by Mikania (*Mikania micrantha*), Guava (*Psidium guajava*), *Acaphyla* sp., and Melastoma (*Melastoma* sp.).
- The most common and preferred site of oviposition of *H.theivora* was stalk between 1st leaf and 2nd leaf of the shoots, which harboured 28.49% of the total number of egg laid, followed by the stalk between 2nd leaf and 3rd leaf (24.92%), stalk between 3rd leaf 4th (24.90%), lower side of mid rib and petiole of 4th leaf (8.72%), lower side of mid rib and petiole of 3rd leaf (7.20%), lower side of mid rib and petiole of 2nd leaf (2.00%), axillary buds (1.40%) and the remaining site of the tea shoot received very less number of eggs which ranged from 0.66-0.99%. Therefore, it was

estimated that 65.72% of the eggs were laid in pluckable portion and rest 34.28% were inserted into non-pluckable region i.e., broken ends of plucked shoots. But when *H. theivora* were challenged with two long-term commonly used insecticides such as endosulfan and deltamethrin topically applied at sub lethal dose, the oviposition preference of *H. theivora* in insecticidal stressed condition was reversed. In comparison to normal condition (i.e. 34.28%) the egg laid in the part of shoot below the pluckable level increased to 59.84 and 58.10%, while only the 40.16 and 41.9% were inserted into pluckable region. It is probably an indication of behavioural resistance of *H. theivora*. The previous experience of insecticide exposure of females might be influencing their change in ovipositing behaviour to save more eggs from insecticide action, since spray of these chemicals reach less in non-pluckable portion of the tea shoots.

- Variation in relative toxicity of different commonly used insecticides was observed against *H. theivora* in different tea subdistricts of the Dooars region of North Bengal. Relative susceptibility (LC_{50}) values for different insecticides varied. *H. theivora* population of Kalchini subdistrict showed less susceptibility to all insecticides tested, whereas that of Damdim and Chulsa subdistricts showed a high susceptibility to most of the tested insecticides. The population of Nagrakata, Dalgong & Binnaguri subdistricts had an intermediate level of susceptibility to different insecticides tested. Endosulfan showed lowest susceptibility against *H.*

theivora in all tea growing subdistricts with high LC_{50} value in all locations in the Dooars tea plantation. The effective field dosages of these insecticides were computed based on LC_{50} values, and when compared with the recommended dosages, it suggested a significant decrease in the susceptibility of the test population for six insecticides such as endosulfan, deltamethrin, λ-cyhalothrin, imidacloprid quinalphos and oxydemeton methyl. In general a significant decrease in susceptibility of *H. theivora* to endosulfan (12.33 to 72.26 fold), deltamethrin (4.02 - 22.40 folds) and imidacloprid (13.61 to 29.16 folds) was recorded. However, there was almost no change in susceptibility level in case of monocrotophos (0.13 to 0.78 fold) and fenpropathrin (0.010 to 0.012 fold), which therefore still prove effective even at lower doses than the recommended ones.

- Persistence (PT values) and Residual (LT_{50} values) toxicity of imidacloprid 17.5 SL, thiomethoxam 25 WG, deltamethrin 2.8 EC, alphamethrin 10 EC, cypermethrin 25 EC, λ-cyhalothrin 5 EC, fenpropathrin 30 EC, monocrotophos 37 SL, Oxydemeton methyl 25 EC, quinalphos 25 EC and endosulfan 35 EC against *H. theivora* were studied by exposing field collected adults for 24 hours to tea leaves treated (TV1) with three concentrations, *i.e.*, 0.05, 0.10 and 0.25 per cent for a period of 4 to 28 days. Persistence of neonicotinoids (thiomethoxam and imidacloprid), synthetic pyrethroids (alphamethrin, deltamethrin, cypermethrin, λ-cyhalothrin, fenpropathrin) and monocrotophos (organophosphate) lasted for a longer duration of 18 - 28 days with

increased PT (product = persistent toxicity) values (938.25 – 1423.13) at 0.25% concentration, whereas oxydemeton methyl, endosulfan, and quinalphos persisted for a relatively short duration (7 to 11 days) with lesser PT values (307.00 – 513.87). But at lower concentration (0.05%), the thiomethoxam, imidacloprid, λ-cyhalothrin, fenpropathrin and monocrotophos exhibited persistence toxicity in the tune of 14-16 days showing higher PT values (689.50 – 806.00), while values for alphamethrin, deltamethrin, cypermethrin, oxydemeton methyl, endosulfan, and quinalphos were in the range of 7-11 days with 124.00 – 573.37 PT. Higher LT_{50} values of 10.59 – 11.27 days were observed at 0.25% concentration of thiomethoxam, λ-cyhalothrin, imidacloprid and fenpropathrin, followed by 8.29 – 9.04 days in case of deltamethrin, alphamethrin and monocrotophos, than moderate 4.11 – 6.99 days in case of cypermethrin and oxydemeton methyl and least 2.92 – 3.02 days in case of endosulfan and quinalphos. Short LT_{50} values (1.11 – 4.98 days) were noted for recommended dose of λ-cyhalothrin, imidacloprid, alphamethrin, deltamethrin, cypermethrin, oxydemeton methyl, endosulfan, and quinalphos. Thus, for combating and delaying the problem of pest resistance either the recommended doses, presently applied in the Dooars plantation, need to be reassessed or the planters need to change their management strategies.

- Laboratory evaluation of ovicidal efficacy of twelve commercial grade synthetic insecticides was done at three concentrations viz., 0.05, 0.1 and

0.25 per cent on eggs of *H. theivora*. The result showed that endosulfan was not showing the ovicidal action with 0.05% concentration. Synthetics such as monocrotophos, quinalphos, profenofos, alphamethrin, cypermethrin, fenpropathrin, λ- cyhalothrin, imidacloprid and thiomethoxam at 0.05%, 0.1% and 0.25% concentration were found responding significantly with egg mortality of 20-97% in laboratory condition. Compared to other groups of insecticides the chosen synthetic pyrethroids insecticides were found highly effective in killing the neonate nymphs of hatched *H. theivora* that successfully came out of treated eggs of *H. theivora*. Ovicidal toxicity (percent mortality of eggs and neonates) of insecticides at higher concentration (0.25%) against *H. theivora* eggs in descending order were deltamethrin > fenpropathrin > λ- cyhalothrin > cypermethrin> imidacloprid > monocrotophos > alphamethrin > profenofos = thiomethoxam > quinalphos > oxydemeton methyl > endosulfan.

- Selection of *Helopeltis theivora* against various sub-lethal concentrations of endosulfan led to an increase in the resistance ratio by 4.419 folds in the fifth generation as compared to first generation. Various biological and developmental traits observed for *H.theivora* revealed that fecundity decreased and total nymphal duration increased significantly in endosulfan-selected population when compared to specimens collected from conventional and organic plantations.

- Variation in relative susceptibility to endosulfan was observed in *H.theivora* populations from different tea growing subdistricts of the Dooars. On the basis of LC_{50} values (mentioned within parenthesis), levels of endosulfan susceptibility in *H. theivora* population could be arranged in the order: - Kalchini (1580.77 ppm) < Dalgong (952.75 ppm) < Binnaguri (938.213 ppm) < Nagrakata (884.95 ppm) < Damdim (544.72 ppm) < Chulsa (269.74 ppm). A computation of the data showed a strong positive correlation among endosulfan susceptibility and body lipid content and the consumption of endosulfan in the Dooars. This finding implies the role of the quantity of body lipid in furnishing greater tolerance to endosulfan and in turn how the use pattern of this insecticide in various tea subdistricts has induced greater tolerance i.e. less susceptibility in *H. theivora* population.
- Three colour variants in male and six in female were identified within *H. theivora* populations of the Dooars, which may presumably be due to pesticide selection pressure.
- Among the crude extracts of 19 native plants screened for anti-insect function, *Nicotiana tobacum, Clerodendron infortunatum, Datura metel, Melia azaderach, Dentella repens* and *Lantana camara* were found potent for there anti-insect properties against *H.theivora.* From preliminary tests, *C. infortunatum* extract could be identified as possessing potential botanical for managing *H. theivora* population in tea.

- Antifeedant and insecticidal activities of *C. infortunatum,* in particular could be established against *H. theivora.* Different solvent extracts (water, methanol, acetone and petroleum ether) of *C.infortunatum* at different concentrations (1, 2, 4 and 8 %) were used. These solvent extracts exhibited mortality of *H. theivora* in the tune of 20 – 60 % in water, 37-77% in petroleum ether, 40-80% in acetone, and the highest mortality 70 – 97 % in methanol extract.

- Significant egg mortality and prolonged incubation period were observed in *H.theivora* eggs when sprayed with solvent extracts of different concentrations of *C.infortunatum* (except water). Higher concentrations (4 and 8 %) of *C.infortunatum* showed higher rate of egg mortality than lower concentrations (1 and 2 %).

- Further, the extracts of *C.infortunatum* were found to be effective in prolongation of incubation and killing the neonate nymphs hatched from the treated eggs.

- High antifeedant activity was noticed in all the concentrations of different solvent extracts of *C.infortunatum* that reduced the feeding spots of *H.theivora* by 38.13 – 87.24 % over untreated control.

- Petroleum ether extract exhibited highest antifeedant property by deterring *H.theivora* than the other 3 solvents.

- No phytotoxic effect of the *C.infortunatum* extract was observed in tea plants. Made tea samples were taint free. Organoleptic test revealed leaf, infusions and liquor strength as good, scoring 6.5 – 7.0 on a 10-point scale.

- Availability and distribution of the weed (*C. infortunatum*) in and around tea growing areas of sub Himalayan Terai and the Dooars, along with its processing for economic utility have been described. In the light of above findings, the feasibility of its inclusion in the current IPM programme of tea pest may be considered.

❖ Different azadirachtin concentrations were evaluated at different doses against the *H. theivora* to find out the variations of its bioefficacy. Sixty five per cent control of infestation was achieved at 50000 ppm azadirachtin conc. whereas 300 and 1500 ppm azadirachtin concentrations gave less than 30% control. Further in case of 3000 and 10000 ppm, azadirachtin concentration 30% to 43% reduction was registered. Therefore Azadirachtin concentration and its quality are the major criteria for getting desired bioactivity in all neem formulations. The combination treatments with commonly used conventional insecticides (neem + endosulfan or neem + deltamethrin) had recorded significant reduction in *H. theivora* incidence even at reduced doses, when compared to sole use of neem formulations or sole insecticidal treatments at recommended doses.

- Higher efficacy of combinations of insecticides with synergists PB (piperonyl butoxide) has been reported for the control of *H.theivora* in the Dooars population. Therefore the use of synergists as one of the countermeasures against the insecticide resistance problem of *H.theivora* is recommended. The combination of deltamethrin +PB, quinalphos +PB and imidacloprid + PB showed 44.60, 16.01 and 11.14 folds increase of toxicity (synergistic ratio) than the respective insecticide alone. Piperonyl butoxide (PB) acted as an oxidase inhibitor. The addition of PB to some extent suppressed the resistance of *H. theivora* to these insecticides, suggesting that the P450 complex may be involved in the mechanism of resistance.
- The bio-efficacy of endosulfan (chlorinated hydrocarbons), monocrotophos (organophosphate) and fenpropathrin (synthetic pyrethroid) at common recommended dilution with different quality of water (Different pH level) as spray fluid was studied against *H. theivora* in field condition. The monocrotophos and fenpropathrin were more severely affected by alkaline water and decomposed much more rapidly than the endosulfan. Particularly in alkaline carrier water (pH 9-10) significantly reduced the efficacy of monocrotophos to the tune of 35.89% to 61.55% if immediately sprayed after mixing, and got reduce to 38.92- 68.06% if the insecticide solution was sprayed after 24 hr of mixing. Neutral and acidic carrier water solution did not induce fall in efficacy. It was cleared from

the study that the spray rig if allowed to stand several hours (24hr) before spraying would cause a substantial reduction in their efficacy.

- The data generated through the present study could be utilized by the tea planters for the best possible chemical practices for management of the major pest, *H. theivora* from the Doors region of North Bengal through efficacious use of chemical pesticides. This may ensure low-cost, eco-compatible pest management package for with minimal residue problems.