Vu Thi Thuong

A STUDY OF SPECIES COMPOSITION AND RELATIONSHIP OF PREDATORY INSECTS WITH INSECT PESTS ON TEA IN PHU THO, AND EFFECTS OF SOME ECOLOGICAL FACTORS ON THEIR OCCURRENCE

Specialty: Ecology
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AN ABSTRACT OF THE DOCTORAL DISSERTATION IN BIOLOGY

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GENERAL INFORMATION

1. Scientific base of the thesis

Studies on the composition of insect pest communities on tea crops have implemented in early 20th century (Du Pasquier, 1932). The composition of natural enemies on insect pests of tea crops have been studied since late 20th century (Nguyen Van Thiep, 1998; Le Thi Nhung, 2002; Pham Van Lam et al., 2003, 2005, 2007a, 2007b, 2008, 2011, Pham Van Lam, 2013); however, these studies have not yet carried out the relationship between predators and their insect pests, and the effect of environmental factors on this relationship. The application of pesticides, inorganic fertilizers and plant growth regulators in tea pest management has been steadily increased and play an essential method of tea growers. Not only does overuse of insecticides kill tea pests, but also promote the appearance of other dangerous insect pests, some minor pests could be a dramatic increase in population and become major pests declining the abundance of natural enemies. VietGAP (Vietnam Good Agriculture Practice) standard on tea trees was started firstly in 2008 and regulated that the application of Integrated Pest Management (IPM) and Integrated Crop Management (ICM) are prioritized, especially recommended biological. Based on scientific literature review and current tea growing issues, this study was implemented with the title “A study of species composition and relationship of predatory insects with insect pests on tea in Phu Tho, and effects of some ecological factors on their occurrence”.

2. Scientific and practical significance

Scientific significance: the species composition of insect pests and their predators in 9 tea growing districts of the province Phu Tho was recorded and update. The study provided the scientific evidence on population densities of some insect pests and their predators on tea crops from 2014 to 2016.

Practical significance: results of the study have provided important scientific evidence in proposing protection, maintainance and releasing predatory insects in insect pest management in the studied tea growing regions.

3. Objectives of the thesis

Study on species composition, population densities of insect pests and their major predators, and prey consumption of some major predators on tea insect pests; impact of some ecological parameters on insect pests, their predators and their interaction; providing valuable scientific knowledge in Integrated Pest Management and sustainable cultivation on tea crops.

4. Content of the thesis
Chapter 1

LITERATURE REVIEW

1.1. Introduction

As a theory, ecosystems are natural to establish their balance; however, impacts of agricultural chemical fertilizers and pesticides have negatively changed and destroyed farming ecosystem composition, structure and natural balance of species population. Based on biological competition, beneficial predatory insects have been studied and applied to control population of insect pests in crop fields and to reduce insecticide application for a sustainable crop production.

Practically, biological control method in a sustainable farming system is an essential and used for a long time; presently this method has been considered and developed significantly at national and international level. Starting from scientific and practical significance, this project was: “A study of species composition and relationship of predatory insects with insect pests on tea in Phu Tho, and effects of some ecological factors on their occurrence”.

1.2. Literature review

1.2.1 International review

*Studies on species composition of insect pests, abundances and density fluctuation of some major insect pests on tea crop

The studies of species composition of insect pests ion tea crops has been published mainly in late 20th century. Tea productivity in South Africa was decreased 50 – 55% that caused by some major insect pests, such as, green planthopper Empoasca flavescens Fabricius, thrips Physothrips setiventris Bagnall, black aphid Toxoptera aurantii Fonscolombe, caterpillars feeding on tea leaves and tea mosquito bug Helopeltis theivora (Rattan, 1992; Sivapalan và Delucchi, 1973). According to result of surveys by Sivapalan et al. (1997a, 1997b) there were 200 pests recorded. Four of these recorded pests were insect pests and mites, including: Empoasca flavescens Fabricius, P. setiventris Bagnall, Helopeltis theivora Waterhouse, Oligonychus coffeae Nietner. Studies on the fluctuation of population densities on these pests have been still carried out in recent years.
*Studies on species composition of predators and population densities of some major insect predators on tea crops*


*Studies on the interaction between predators and their preys on tea crops*

Somnath *et al.* (2010) studied the interaction between coccinellid predators and their prey aphids. The interaction between coccinellid predators and their preys planthopper and aphids were studied by Studies of Somnath and Rahman (2014), Chowdhury *et al.* (2008). Nitin *et al.* (2017) studied the interaction between the predatory bug *Sycanus galbanus* Distant and tea caterpillars under laboratory conditions.

*Studies on impacts of ecological parameters on insect pests, predators and their interaction on tea crops*

Most of studies on predators and their prey have been published in China, India, a few of them were studied in Bangladesh, Malaysia, Taiwan, Japan,… Most of authors have studied effects of ecological factors on the population density of insect pests and their preys, but studies on impacts of ecological factors on interaction of predators and their preys are unknown or little.

1.2.2. Literature review in Vietnam

*Study results on species composition, abundance and population density fluctuation of major insect pests on tea crops*

*Study results on species composition of key preators and their desity population dynamic on tea crop*

The first study on natural enemies on tea crops was carried out by Nguyen Van Thiep (1998, 2000). His study found 13 natural enemies on tea crops in Phu Ho, 6 of these enemies recorded were 4 mites, 1 predatory bug and 1 ant specie. Le Thi Nhung (2002) found 79 natural enemies during survey time of 1996 – 1999. Pham Van lam (2013) also found 113 natural enemies, and 56 of these species were categorized, in which 37 species were predatory bugs.

*Study results on interaction of predators and their key insect preys on tea crops*

Until now all most of studies on predators were implemented on some crops such as, soybean, peanut, vegetables, rice and maize. However, studies on predatory species on tea crops are little known. Studies on natural enemies in other crops have been started early, but these studies on tea crops were very little. Species composition of natural enemies and Integrated Pest Management (IPM) on tea crops has been implemented since late 20th century. Since years of 20th century, the application of IPM has been recommended. During the first period of the IPM application, some pest control methods of IPM have been applied, including biological control to increase population of natural enemies in tea fields. However, scientific results on biology and application of natural enemies in tea fields are unknown or little.

*Studies on impacts of ecological factors on predators, their preys and interaction on tea crops*

Nguyen Van Thiep (1998, 2000) and Le Thi Nhung (2002) studied impact of environmental factors, tea cultivars, shading trees, cultivation techniques, harvesting methods, pesticide application, tea pruining, harvesting methods and hilly terrain on insect pest densities and their predators, was carried out, but study on interaction predators and their preys was unknown.

**CHAPTER 2: RESEARCH METHODOLOGY**

2.1. Materials and scales of research

Research materials: insect pests and major insect pests on tea. Predators of major insect pests on tea.

2.2. Time and study sites

The project was implemented from December 2013 to December 2017.

- Conduct surveys on species composition of insect pests and predators on tea crops in 9 districts, and made research plots in Ha Hoa and Yen Lap districts of the province Phu Tho:
- Classify and name major insect pests and their predators on tea crop at Insect Ecology Lab of Institute of Ecology and Biological Resources.

2.3. Research proposal outline
- Study on species composition, seasonal occurrence and population density dynamic of some major insect pests at the study sites.
- Study on composition of predators and their preys, population density dynamic of some predators on tea crops at the study sites.
- Study on the interaction of some predators and their preys-major insect pests on tea crops in the study sites.
- Study on impacts of ecological factors (tea cultivar, shading trees, growing and harvesting methods, pruning technique, pesticide application) on insect pests, predators and their interaction on tea crops at the study sites.

2.4. Research materials
Research materials were tea cultivars including LDP1, LDP2, PH1, Trung Du và TRI777. Research equipments included sweep netting, insect pitfall traps, insect brushes, pan traps, aluminum trays with the dimension of 35 x 25 x 5cm, gasoline, washer detergent, and other equipment, such as notebooks, pens,…

2.5.1. Study on species composition, abundance and population density dynamic of some major insect pests at study sites.
Survey methods were based on the method of Plant Protection Research Institute (1997); Vietnam Ministry of Agriculture and Rural Development (2003), Nguyen Van Hung and Nguyen Van Tao (2006). Specimens of insect pests were recorded and stored by the research methods of Center for Northern Plant Protection (1992) and Technology Science Board (1967).

2.5.2. Study on species composition, abundance and population density dynamics of predators and their preys on tea crops at the study sites
Survey on composition of predators was conducted along with surveys of insect pests on tea. For the collection of predator samples, the study used pitfall traps for predatory ants (noted from the insect sampling collection of Amateur Entomologists, 2015), and trap–nesting bees for predatory bees (noted from the sampling method of Christophe, 2012). Study on population density dynamics of major predators on tea crops was conducted according to the method of Plant Protection Research Institute – PPRI (1997). Predatory coccinellids were identified using diagnostic method of Hoang Duc Nhuan, predatory bugs identified with the key of Claver and Ambrose (2002); Vennison and Ambrose (1992), predatory bees indentified with the method of Nguyen et al.(2006, 2011); Nguyen and Kojima, 2014; Saito - Morooka et al.(2015).
Compare composition of insect pests and their predators of this study with the research results conducted by PPRI (1976), Pham Van Lam et al. (2007a, 2011) and Pham Van Lam (2013).

2.5.3. **Study on the interaction of predators and their preys on tea crops at the study sites:** used the method of correlation calculation by Nguyen Thanh Hai and Do Tat Luc (2008).

2.5.4. **Study on impacts of ecological factors on predators, insect pests and their interaction on tea crops at the study sites**

* Impact of tea cultivars on some insect pests, predators and their interaction:*

The study was designed with 5 treatments as below:

Treatment CT1: tea cultivar LDP1.
Treatment CT2: tea cultivar LDP2.
Treatment CT3: tea cultivar PH1.
Treatment CT4: tea cultivar Trung du.
Treatment CT5: tea cultivar TRI777

* Effect of shade trees was designed with 2 treatments:*
Treatment CT1 – tree-shaded tea.
Treatment CT2 – tree- unshaded tea.

* Effect of tea cultural practices was designed with 2 treatments*
Treatment CT1 – well-cared tea.
Treatment CT2 – poorly-cared tea.

* Effect of plucking techniques was designed with 2 treatments*
Treatment CT1 – thirdly plucked tea.
Treatment CT2 – thoroughly-plucked tea.

* Impact of tea pruning techniques was designed with 2 treatments*
Treatment CT1 – early pruned tea.
Treatment CT2 – late pruned tea.
Treatment CT3 – lightly pruned tea.
Treatment CT4 – deeply pruned tea.

* Effect of insecticide application: * Monitor and record density of insect pests and predators on 2 research treatments: insecticide application of tea growers and no insecticide application.

2.6. **Data analysis**

Data of the study were analyzed by MS Excel 2010, presented by tables, figures and pictures.

2.7. **Basic natural, economic and social conditions for the same study**
Phu Tho is a province in the midland of the Northern, where the three major rivers of the Red, “Da” and “Lo” rivers meet. Ha Hoa district is located in the transitional position between the midland and mountainous areas in the north, which is influenced by two climate zones between east and west, and the climate is divided into two distinct seasons. Ha Hoa's tea land is mainly low hill land, poor nutrition and sour.

CHAPTER 3: RESULTS AND DISCUSSIONS

3.1. Study on species composition, abundance and population density dynamic of major insect pests on tea crops in Phu Tho province

Survey on species composition of tea insect pests was conducted in 9 districts of Phu Tho province from 2014 to 2016. The survey result recorded 56 insect pests belonging to 8 orders and 30 families. There were 3 new insect pests recorded in Phu Tho province including Biston suppressaria Guence, Chalcocelis albigutata Snellen, Archips sp. There were 7 species with high abundance level (25 – 50%), in which 6 of these species were of Lepidoptera order. Only 3 species had abundance level of up to 50%, including thrips P. setiventris Bagnall, tea green planthopper Empoasca flavescens Fabricius, tea aphid Toxoptera aurantii Fonscolombe.

The survey on the population density of major insect pests found that density of tea green planthopper was highest in April and October. The highest density of thrips was in January and July, while the high density of tea aphids was in dry season (from August to April) and fluctuated in other moths. The caterpillars feeding on tea occurred around the year and reached its highest density in September.

3.2. Study on species composition of predators, their preys and population density dynamic of some predators on tea in Phu Tho province

In Phu Tho province, the study recorded 51 predators belonging to 7 orders and 15 families. There were 4 major predators in tea field of Phu Tho province, including predatory heteropteran Sycanus croceovittatus Dohrn, predatory heteropteran O. sauteri, coccinella Menochilus sexmaculatus (Fabricius), red coccinella Micraspis discolor (Fabricius). One new predator identified was Polistes communalis Nguyen, Vu & Carpenter 2017; and there were 4 predators recorded new on tea in Phu Tho province, including Cytorhinus lividipennis Reuter, Poliditus peramatus Uhler, Andrallus spinidens Fabricius, O. sauteri.

The study result showed that the occurrence of 4 major predators recorded was around the year and had high density at different time: S. croceovittatus (in Jule), O.
Sauteri (in May an October), M. discolor (in July and August), M. Sexmaculatus (in Jule and November) during the research period of 3 years.

3.3. Interaction of major predators and ther preys on tea in Phu Tho province

3.3.1. Interaction of major predatory bugs and their preys on tea

This interaction in the tea fields were no correlated, and only had significantly correlation at specific time when the density of predators and their preys on tea was high. The interaction between predatory heteropteran O. sauteri and the prey thrip P. setiventris was significant correlated from May to October during the research period of 3 years (figure 3.12). The interaction between predatory heteropteran S. croceovittatus and caterpillars had a highest correlation from April to September during the period of 3 research years (hinh 3.13); and there was a significant correlation between coccinella M. Discolor, M. sexmaculatus and their prey tea aphids; and tea aphids also have a high correlation from April to July in the period of research.
Figure 3.12. The relationship between *O. sauteri* with *P. setiventrhis* on tea in Phu Tho
Figure 3.13. The relationship between *S. croceovittatus* with the group of tea lepidopterous pests on tea in Phu Tho
3.3.2. Relationship of some species of ladybug common to T. aurantii e in Phu Tho

Figure 3.14. The relationship between M. discolor with T. aurantii on tea in Phu Tho
Figure 3.15. The relationship between *M. sexmaculatus* with *T. aurantii* on tea in Phu Tho
3.4. Effects of some ecological factors on population density and relationship of predatory insects with major pest insects of tea in Phú Thọ.

3.4.1. Effects of tea cultivars on population density and relationship of predatory insects with major pest insects

*Effect of tea cultivars on population density of tea pest and predatory insects*

Among five tea cultivars surveyed, “Trung Du” of Chinese origin was the most heavily infested by the thrip *P. setiventris*, the hybrid tea cultivars “LDP1” and “LDP2” were the least infested. The mean density of the predatory heteropteran *O. sauteri* was highest on “Trung Du”, lowest on “LDP1” and “LDP2”. Besides, ratios of *O. sauteri* to *P. setiventris* were different among tea cultivars, viz. 1:42 on “Trung Du”, 1:48 on “TRI777”, 1:54 on “PH1”, 1:68 on “LDP2” and 1: 90 on “LDP2”.

For the occurrence of lepidopterous pests, the mean densities were higher on “Trung Du” and “TRI777” than on three remaining cultivars. While, the mean densities of predatory heteropteran *S. croceovittatus* were higher on “TRI777”, “PH1” and “Trung Du” than on “LDP1” and “LDP2”. Ratios of *S. croceovittatus* to lepidopterous pests were the same (1:2) on three cultivars “Trung Du”, “PH1” and “TRI777”, and also the same (1:3) on “LDP1” and “LDP2”.

For the occurrence of the Tea Green Fly *E. flavescens*, its mean densities were highest on “Trung Du”, lowest on “LDP1”, “LDP2” and “PH1”. The mean densities of group of predatory heteropterans were higher on Trung Du and TRI777 than on three remaining cultivars. The ratios of predatory heteropterans to *E. flavescens* were highest on “Trung Du” and “LDP2” (both 1:17), followed by that on “LDP1” (1:15), lowest on “PH1” and “TRI777” (both 1:14).

For predatory coccinellids, the mean densities of *M. discolor* and *M. sexmaculatus* both were highest on “LDP1” and “LDP2”, lowest on “PH1” and “TRI777”. The mean densities of group of coccinellids were higher on “LDP1” and “LDP2” that on three remaining cultivars. Theirs prey, the thrip *Toxoptera aurantii* Fonscolombe, was also highest in mean densities on “LDP1” and “LDP2”, and lowest on “PH1” and “TRI777”. Ratios of *M. discolor* to *Toxoptera aurantii* were highest on “PH1” and “TRI777” (both 1:24), followed by that on “TRI777” and “LDP1” (both 1:23), lowest on “LDP2” (1:22). Ratios of *M. sexmaculatus* to *T. aurantii* were also highest on “PH1” and “TRI777” (both 1:29), followed by that on “LDP2” (1:28), lowest on “TRI777” and “LDP1” (both 1:27). Ratios of group of
coccinellids to *T. aurantii* were the same (1:11) on “LDP2” and “Trung Du” and also the same (1:10) on three remaining cultivars.

* Effect of tea cultivars on relationship of some predatory insects with their prey (major tea pests) in Phú Thọ in 2016

Table 3.14. Effect of tea cultivars on relationship of some predatory insects with their prey (major tea pests) in Phú Thọ in 2016

<table>
<thead>
<tr>
<th>No</th>
<th>Relationship of predatory insects with their prey</th>
<th>Correlation coefficient (R)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>LDP1</td>
</tr>
<tr>
<td>1.</td>
<td><em>O. sauteri</em> to <em>P. setiventris</em></td>
<td>-0.89</td>
</tr>
<tr>
<td>2.</td>
<td><em>S. croceovittatus</em> to the group of tea lepidopterous pests</td>
<td>-0.82</td>
</tr>
<tr>
<td>3.</td>
<td>Group of predatory heteropterans to <em>E. flavescens</em></td>
<td>-0.65</td>
</tr>
<tr>
<td>4.</td>
<td><em>M. discolor</em> to <em>T. aurantii</em></td>
<td>-0.97</td>
</tr>
<tr>
<td>5.</td>
<td><em>M. sexmaculatus</em> to <em>T. aurantii</em></td>
<td>-0.75</td>
</tr>
<tr>
<td>6.</td>
<td>Group of coccinellids to <em>T. aurantii</em></td>
<td>-0.85</td>
</tr>
</tbody>
</table>

Predatory insects exhibited varied roles in controlling tea pest populations among tea cultivars. Correlations of predators to their prey (*O. sauteri* with *P. setiventris*, *S. croceovittatus* with the group of tea lepidopteran pests, the group of predatory heteropterans with *E. flavescens*, *M. discolor* with *T. aurantii*, *M. sexmaculatus* with *T. aurantii* and group of coccinellids with *T. aurantii*) were negative and strong to very strong on tea hybrids (“LDP1” and “LDP2”) and cultivar “TRI777”, while those correlations were weaker on “PH1” and weakest on “Trung Du” with correlations of *S. croceovittatus* to the group of tea lepidopterous pests, group of predatory heteropterans to *E. flavescens*, *M. discolor* to *T. aurantii*, *M. sexmaculatus* to *T. aurantii* being negative (R ranging from - 0.32 to -0.49) (table 3.14).

3.4.2. Effects of shade trees on population density and relationship of predatory insects with major pest insects

* Effect of shade trees on population density of tea pest and predatory insects
During five months (from June to October 2016) of survey, the mean density of the predatory heteropteran *O. sauteri* was found to be higher on tree–shaded tea (1.28 individuals/m²) than on tree–unshaded tea (0.92 individuals/m²) (LSD₀.₀₅ = 0.15). While, for its prey, the thrip *P. setiventris*, the mean density was lower on tree–shaded tea (42.8 individuals/m²) than on tree–unshaded tea (49.3 individuals/m²) (LSD₀.₀₅ = 3.2). Moreover, shade trees affected on the ratio of *O. sauteri* to *P. setiventris*, which was 1:33 on tree–shaded tea, and 1:53 on tree–unshaded tea.

For the predatory heteropteran *S. croceovittatus*, the mean density was not different between tree–shaded (1.12 individuals/m²) and tree–unshaded tea (1.08 individuals/m²) (LSD₀.₀₅ = 0.7). Also no difference was found in the mean density of the group of lepidopterous pests between tree–shaded (3.63 individuals/m²) and tree–unshaded tea (3.55 individuals/m²) (LSD₀.₀₅ = 0.91). Moreover, ratio of *S. croceovittatus* to lepidopterous pests on tree–shaded tea was the same as that on tree–unshaded tea (1:3).

Group of predatory heteropterans was found to be higher in mean density on tree–shaded tea (2.93 individuals/m²) that on tree–unshaded tea (2.74 individuals/m²) (LSD₀.₀₅ = 0.11). On contrary, their prey, the Tea Green Fly *E. flavescens*, was lower in mean density on tree–shaded tea (63.05 individuals/m²) that on tree–unshaded tea (70.44 individuals/m²) (LSD₀.₀₅ = 3.31). The ratio of the group of predatory heteropterans to *E. flavescens* on tree–shaded and tree–unshaded tea was 1:22 and 1:26 respectively.

For predatory coccinellids, the mean densities of *M. discolor* and *M. sexmaculatus* were also higher on tree–shaded tea (1.50 and 1.21 individuals/m² respectively) than on tree–unshaded tea (1.30 and 0.98 individuals/m²). The group of coccinellids was also higher on tree–shaded tea (2.93 individuals/m²) than on tree–unshaded tea (2.63 individuals/m²) (LSD₀.₀₅ = 0.20). Prey of coccinellids, the tea aphid *T. aurantii*, was higher in mean density on tree–shaded tea (49.5 individuals/m²) than on tree–unshaded tea (38.7 individuals/m²) (LSD₀.₀₅ = 2.11). Ratios of *M. discolor*, *M. sexmaculatus* and the group of coccinellids to their prey were 1:33, 1:41 and 1:17 respectively on tree–shaded tea, 1:30, 1:40 and 1:15 respectively on tree–unshaded tea.

*Effect of shade trees on relationship of some predatory insects with their prey (major tea pests)*
3.16. Effect of shade trees on relationship of some predatory insects with their prey (major tea pests) in Phú Thọ in 2016

<table>
<thead>
<tr>
<th>No</th>
<th>Relationship of predatory insects with their prey</th>
<th>Correlation coefficient (R)</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Tree–shaded tea</td>
</tr>
<tr>
<td>1.</td>
<td>O. sauteri to P. setiventris</td>
<td>-0.91</td>
</tr>
<tr>
<td>2.</td>
<td>S. croceovittatus to the group of tea lepidopterous pests</td>
<td>-0.47</td>
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<td>3.</td>
<td>Group of predatory heteropterans to E. flavescens</td>
<td>-0.80</td>
</tr>
<tr>
<td>4.</td>
<td>M. discolor to T. aurantii</td>
<td>-0.90</td>
</tr>
<tr>
<td>5.</td>
<td>M. sexmaculatus to T. aurantii</td>
<td>-0.92</td>
</tr>
<tr>
<td>6.</td>
<td>Group of coccinellids to T. aurantii</td>
<td>-0.95</td>
</tr>
</tbody>
</table>

On tree–shaded and tree–unshaded tea, predatory insects exhibited varied roles in controlling tea pest populations. Correlations of predators to their prey (O. sauteri with P. setiventris, S. croceovittatus with the group of tea lepidopteran pests, the group of predatory heteropterans with E. flavescens, M. discolor with T. aurantii, M. sexmaculatus with T. aurantii and group of coccinellids with T. aurantii) were negative and strong to very strong on tree–shaded tea, while on tree–unshaded tea, those correlations were weaker.

3.4.3. Effects of cultural practices on population density and relationship of predatory insects with major pest insects

* Effect of cultural practices on population density of tea pest and predatory insects

During five months (from June to October 2016) of survey, the mean density of the predatory heteropteran O. sauteri was found to be lower on well–cared tea (1.26 individuals/m²) than on poorly–cared tea (1.43 individuals/m²) (LSD₀.₀⁵ = 0.07). For its prey, the thrip P. setiventris, the mean density was also lower on well–cared tea (32.8 individuals/m²) than on poorly–cared tea (42.7 individuals/m²) (LSD₀.₀⁵ = 1.50). The ratio of O. sauteri to P. setiventris on well–cared and poorly–cared tea was 1:26 and 1:33 respectively.

Similarly to O. sauteri, the predatory heteropteran S. croceovittatus was also lower in mean density on well–cared tea (0.77 individuals/m²) than on poorly–cared tea (1.26 individuals/m²) (LSD₀.₀⁵ = 0.08). Its prey, a group of tea lepidopterous pests, was lower on well–cared tea (2.22 individuals/m²) than on poorly–cared tea (2.71
individuals/m$^2$) (LSD$_{0.05} = 0.12$). The ratio of $S.\ croceovittatus$ to the lepidopterous pests on well– and poorly–cared tea was 1:3 and 1:2 respectively.

Group of predatory heteropterans and the prey, the Tea Green Fly $E.\ flavescens$, were found to be also lower in mean density on well–cared tea (3.10 and 52.4 individuals/m$^2$ respectively) that on poorly–cared tea (3.34 and 67.8 individuals/m$^2$ respectively). The ratio of the group of predatory heteropterans to $E.\ flavescens$ on well–cared and poorly–cared tea was 1:17 and 1:20 respectively.

For predatory coccinellids, the mean densities of $M.\ discolor$ and $M.\ sexmaculatus$ were also lower on well–cared tea (1.23 and 1.12 individuals/m$^2$ respectively) than on poorly–cared tea (1.53 and 1.48 individuals/m$^2$). The group of coccinellids was lower on well–cared tea (2.89 individuals/m$^2$) than on poorly–cared tea (3.26 individuals/m$^2$) (LSD$_{0.05} = 0.18$). Prey of coccinellids, the tea aphid $T.\ aurantii$, was lower in mean density on well–cared tea (35.3 individuals/m$^2$) than on poorly–cared tea (52.7 individuals/m$^2$) (LSD$_{0.05} = 2.50$). The ratios of $M.\ discolor$, $M.\ sexmaculatus$ and the group of coccinellids to their prey were 1:19, 1:32 and 1:12 respectively on well–cared tea, 1:34, 1:37 and 1:16 respectively on poorly–cared tea.

**Table 3.18. Effect of cultural practices on relationship of some predatory insects with their prey (major tea pests) in Phú Thọ in 2016**

<table>
<thead>
<tr>
<th>No</th>
<th>Relationship of predatory insects with their prey</th>
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<tr>
<td>1</td>
<td>$O.\ sauteri$ to $P.\ setiventris$</td>
<td>-0.86</td>
</tr>
<tr>
<td>2</td>
<td>$S.\ croceovittatus$ to the group of tea lepidopterous pests</td>
<td>-0.78</td>
</tr>
<tr>
<td>3</td>
<td>Group of predatory heteropterans to $E.\ flavescens$</td>
<td>-0.74</td>
</tr>
<tr>
<td>4</td>
<td>$M.\ discolor$ to $T.\ aurantii$</td>
<td>-0.80</td>
</tr>
<tr>
<td>5</td>
<td>$M.\ sexmaculatus$ to $T.\ aurantii$</td>
<td>-0.85</td>
</tr>
<tr>
<td>6</td>
<td>Group of coccinellids to $T.\ aurantii$</td>
<td>-0.93</td>
</tr>
</tbody>
</table>

Predatory insects exhibited varied roles in controlling tea pest populations. Correlations of predatory heteropterans to their prey ($O.\ sauteri$ with $P.\ setiventris$, $S.\ croceovittatus$ with the group of tea lepidopteran pests, the group of predatory heteropterans with $E.\ flavescens$) were higher in absolute values on well–cared tea than on poorly–cared tea, indicating their greater role in controlling tea pests on well–cared tea than poorly–cared tea. While for predatory coccinellids, the correlation of
M. discolor with T. aurantii was slightly weaker on well–cared tea than on poorly–cared tea, that of M. sexmaculatus with T. aurantii was the same, and predatory coccinellids as a whole was stronger on well–cared tea than on poorly–cared tea.

3.4.4. Effects of tea plucking techniques on population density and relationship of predatory insects with major pest insects

* Effect of tea plucking techniques on population density of tea pest and predatory insects

During five months (from June to October 2016) of survey, the mean density of the predatory heteropteran O. sauteri was found to be lower on thirdly–plucked tea (1.04 individuals/m$^2$) than on thoroughly–plucked tea (1.82 individuals/m$^2$) (LSD$_{0.05} = 0.07$). While, for its prey, the thrip P. setiventris, the mean density was higher on thirdly–plucked tea (38.5 individuals/m$^2$) than on thoroughly–plucked tea (32.9 individuals/m$^2$) (LSD$_{0.05} = 1.32$). The ratio of O. sauteri to P. setiventris was 1:37 on thirdly–plucked tea, and 1:18 on thoroughly–plucked tea.

For the predatory heteropteran S. croceovittatus, the mean density was lower on thirdly–plucked tea (0.78 individuals/m$^2$) than on thoroughly–plucked tea (1.12 individuals/m$^2$) (LSD$_{0.05} = 0.04$). While, for its prey, the group of lepidopterous pests, the mean density was higher on thirdly–plucked tea (3.08 individuals/m$^2$) than on thoroughly–plucked tea (2.04 individuals/m$^2$) (LSD$_{0.05} = 0.12$). The ratio of S. croceovittatus to lepidopterous pests was 1:4 on thirdly–plucked tea, 1:2 on thoroughly–plucked tea.

Group of predatory heteropterans was found to be also lower in mean density on thirdly–plucked tea (2.63 individuals/m$^2$) that on thoroughly–plucked tea (3.56 individuals/m$^2$) (LSD$_{0.05} = 0.15$). On contrary, their prey, the Tea Green Fly E. flavescens, was higher in mean density on thirdly–plucked tea (59.3 individuals/m$^2$) that on thoroughly–plucked tea (51.3 individuals/m$^2$) (LSD$_{0.05} = 3.26$). The ratio of the group of predatory heteropterans to E. flavescens on thirdly–plucked and thoroughly–plucked tea was 1:23 and 1:14 respectively.

For predatory coccinellids, the mean densities of M. discolor and M. sexmaculatus were also lower on thirdly–plucked tea (1.37 and 0.93 individuals/m2 respectively) than on thoroughly–plucked tea (1.42 and 1.43 individuals/m2). The group of coccinellids was also lower on thirdly–plucked tea (2.79 individuals/m$^2$) than on thoroughly–plucked tea (3.11 individuals/m$^2$) (LSD$_{0.05} = 0.15$). While, prey of coccinellids, the tea aphid T. aurantii, was higher in mean density on thirdly–plucked tea (55.9 individuals/m$^2$) than on thoroughly–plucked tea (36.5 individuals/m$^2$) (LSD$_{0.05} = 1.68$). Ratios of M. discolor, M. sexmaculatus and the
group of coccinellids to their prey were 1:41, 1:60 and 1:20 respectively on thirdly–plucked tea, 1:26, 1:25 and 1:12 respectively on thoroughly–plucked tea.

*Effect of tea plucking techniques on relationship of some predatory insects with their prey (major tea pests) in Phú Thọ in 2016*

On thirdly–plucked and thoroughly–plucked tea, predatory insects exhibited varied roles in controlling tea pest populations. Correlations of predators to their prey (*O. sauteri* with *P. setiventris*, *S. croceovittatus* with the group of tea lepidopteran pests, the group of predatory heteropterans with *E. flavescens*, *M. discolor* with *T. aurantii*, *M. sexmaculatus* with *T. aurantii* and group of coccinellids with *T. aurantii*) were negative and very strong on thoroughly–plucked tea, while on thirdly–plucked tea, those correlations were weaker (table 3.20).

**Table 3.20. Effect of tea plucking techniques on relationship of some predatory insects with their prey (major tea pests) in Phú Thọ in 2016**

<table>
<thead>
<tr>
<th>No</th>
<th>Relationship of predatory insects with their prey</th>
<th>Correlation coefficient (R)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>thirdly–plucked tea</td>
</tr>
<tr>
<td>1.</td>
<td><em>O. sauteri</em> to <em>P. setiventris</em></td>
<td>-0.61</td>
</tr>
<tr>
<td>2.</td>
<td><em>S. croceovittatus</em> to the group of tea lepidopterous pests</td>
<td>-0.75</td>
</tr>
<tr>
<td>3.</td>
<td>Group of predatory heteropterans to <em>E. flavescens</em></td>
<td>-0.54</td>
</tr>
<tr>
<td>4.</td>
<td><em>M. discolor</em> to <em>T. aurantii</em></td>
<td>-0.78</td>
</tr>
<tr>
<td>5.</td>
<td><em>M. sexmaculatus</em> to <em>T. aurantii</em></td>
<td>-0.74</td>
</tr>
<tr>
<td>6.</td>
<td>Group of coccinellids to <em>T. aurantii</em></td>
<td>-0.87</td>
</tr>
</tbody>
</table>

*3.4.5. Effects of tea pruning techniques on population density and relationship of predatory insects with major pest insects*

*Effect of pruning types on population density of tea pest and predatory insects*

During five months (from June to October 2016) of survey, the mean density of the predatory heteropteran *O. sauteri* was found to be lower on deeply–pruned tea (1.65 individuals/m2) than on lightly–pruned tea (2.16 individuals/m2) (LSD$_{0.05}$ = 0.09). While, for its prey, the thrip *P. setiventris*, the mean density was higher on deeply–pruned tea (21.8 individuals/m2) than on lightly–pruned tea (16.3
individuals/m2) (LSD_{0.05} = 0.85). The ratio of *O. sauteri* to *P. setivensis* on deeply– and lightly–pruned tea was 1:13 and 1:8 respectively.

Like *O. sauteri*, the predatory heteropteran *S. croceovittatus* was also lower in mean density on deeply–pruned tea (0.62 individuals/m2) than on lightly–pruned tea (0.84 individuals/m2) (LSD_{0.05} = 0.04). Its prey, a group of tea lepidopterous pests, in contrast, was higher on deeply–pruned tea (1.48 individuals/m2) than on lightly–pruned tea (1.16 individuals/m2) (LSD_{0.05} = 0.06). Ratio of *S. croceovittatus* to the lepidopterous pests on deeply–pruned and lightly–pruned tea was 1:3 and 1:2 respectively.

In a relation to prey, the Tea Green Fly *E. flavescens*, the group of predatory heteropterans was also lower in mean density on deeply–pruned tea (3.76 individuals/m2) than on lightly–pruned tea (4.28 individuals/m2) (LSD_{0.05} = 0.21) while the mean density of the prey was higher on deeply–pruned tea (48.22 individuals/m2) than on lightly–pruned tea (39.40 individuals/m2) (LSD_{0.05} = 1.56). The ratio of the group of predatory heteropterans to their prey on deeply–pruned and lightly–pruned tea was 1:13 and 1:9 respectively.

For predatory coccinellids, the mean densities of *M. discolor* and *M. sexmaculatus* were also lower on deeply–pruned tea (1.25 and 1.33 individuals/m2 respectively) than on lightly–pruned tea (2.81 and 2.75 individuals/m2). As combined data, the group of coccinellids was also lower on deeply–pruned tea (2.98 individuals/m^2) than on lightly–pruned tea (6.06 individuals/m^2) (LSD_{0.05} = 0.22). Prey of coccinellids, the tea aphid *T. aurantii*, was higher in mean density on deeply–pruned tea (38.32 individuals/m^2) than on lightly–pruned tea (13.32 individuals/m^2) (LSD_{0.05} = 0.68). The ratios of *M. discolor*, *M. sexmaculatus* and the group of coccinellids to their prey were 1:31, 1:29 and 1:13 respectively on deeply–pruned tea, 1:30, 1:5 and 1:2 respectively on lightly–pruned tea.

An analysis of correlation showed that predatory insects exhibited varied roles in controlling populations of tea insect pests on the two types of tea pruning. All six pairs of relationship of predators with prey (*O. sauteri* with *P. setivensis*, *S. croceovittatus* with the group of tea lepidopterous pests, the group of predatory heteropterans with *E. flavescens*, *M. discolor* with *T. aurantii*, *M. sexmaculatus* with *T. aurantii* and group of coccinellids with *T. aurantii*) had stronger negative correlation on lightly pruned tea that on deeply pruned tea (table 3.22).

* Effect of tea pruning types on relationship of some predatory insects with their prey (major tea pests) in Phú Thọ in 2016
Table 3.22. Effect of tea pruning types on relationship of some predatory insects with their prey (major tea pests) in Phú Thọ in 2016

<table>
<thead>
<tr>
<th>No</th>
<th>Relationship of predatory insects with their prey</th>
<th>Correlation coefficient (R)</th>
<th>Deeply–pruned tea</th>
<th>Lightly–pruned tea</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td><em>O. sauteri</em> to <em>P. setiventris</em></td>
<td>-0.49</td>
<td>-0.71</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td><em>S. croceovittatus</em> to the group of tea lepidopterous pests</td>
<td>-0.81</td>
<td>-0.83</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Group of predatory heteropterans to <em>E. flavescens</em></td>
<td>-0.29</td>
<td>-0.71</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td><em>M. discolor</em> to <em>T. aurantii</em></td>
<td>-0.47</td>
<td>-0.92</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td><em>M. sexmaculatus</em> to <em>T. aurantii</em></td>
<td>-0.63</td>
<td>-0.79</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Group of coccinellids to <em>T. aurantii</em></td>
<td>-0.65</td>
<td>-0.89</td>
<td></td>
</tr>
</tbody>
</table>

* Effect of time of tea pruning on population density of pest and predatory insects

The mean density of *O. sauteri* in the first three months of the year (from January to March 2016) was higher on early–pruned tea (2.38 individuals/m²) than on late–pruned tea (1.83 individuals/m²) (LSD<sub>0.05</sub> = 0.23). However, in the following three months (April to June 2016), the density of this species was not different (1.88 vs 1.71 individuals/m², LSD<sub>0.05</sub> = 0.35) between these treatments of pruning time. A similar trend was also found for the occurrence of the thrip *P. setiventris*. Its mean density on early pruned tea was higher than that on late–pruned tea (9.4 vs 8.5 individuals/m², LSD<sub>0.05</sub> = 0.28) in the first three months, but was not different (28.7 vs 28.8 individuals/m² respectively) between the two treatments in the next three months. The ratio of *O. sauteri* to *P. setiventris* in the first three months on early– and late–pruned tea was 1:4 and 1:5 respectively, in the following three months was 1:15 and 1:17 respectively.

For the predatory heteropteran *S. croceovittatus*, its mean density in the first three months was higher on early–pruned tea (1.10 individuals/m²) that on late–pruned tea (0.91 individuals/m²) (LSD<sub>0.05</sub> = 0.02), but was not different (0.64 vs 0.65 individuals/m², LSD<sub>0.05</sub> = 0.36) in the following three months between the two treatments of pruning time. Its prey, group of lepidopterous pests, also had a similar trend that was higher in mean density on early–pruned tea (2.15 individuals/m²) than on late–pruned tea (1.88 individuals/m²) (LSD<sub>0.05</sub> = 0.20) in the three first months, but was not different (3.47 vs 3.37 individuals/m², LSD<sub>0.05</sub> = 0.32). in the following three months between the two treatments. The ratio of *S. croceovittatus* to
lepidopterous pests in the first three months on early– and late–pruned tea was the same as 1:2; in the following three months was 1:5 and 1:6 respectively.

For the group of predatory heteropterans, their mean density in the first three months was also higher on early–pruned tea (4.76 individuals/m²) than on late–pruned tea (4.05 individuals/m²) (LSD$_{0.05} = 0.33$), but was not different (3.48 and 3.15 individuals/m²) (LSD$_{0.05} = 0.49$) between the two treatments of pruning time. Prey of the heteropterans, the Tea Green Fly _E. flavescens_, has also the similar trend that it’s mean density in the first three months was also higher on early–pruned tea (33.64 individuals/m²) than on late–pruned tea (23.92 individuals/m²) (LSD$_{0.05} = 5.26$), but not different (57.92 vs 58.64 individuals/m², LSD$_{0.05} = 3.82$) in the following three months between the two treatments. The ratio of group of predatory heteropterans to _E. flavescens_ in the first three months on early– and late – pruned tea was 1:7 and 1:6 respectively, in the following three months was 1:17 and 1:19 respectively.

For coccinellids, the mean densities of _M. discolor_, _M. sexmaculatus_ and the group of coccinellids during six months of survey on early–pruned tea were higher than those on late–pruned tea. In the first three months, the densities of _M. discolor_, _M. sexmaculatus_ and the group of coccinellids were higher on early–pruned tea (4.78, 5.80 and 11.08 individuals/m² respectively) than on late–pruned tea (1.09, 1.27 and 2.76 individuals/m² respectively); and again in the following three months, their densities were higher on early–pruned tea (3.29, 3.74 and 7.52 individuals/m² respectively) than on late–pruned tea (1.48, 1.38 and 3.26 individuals/m² respectively).

Meanwhile, their prey, the aphid _T. aurantii_, was also higher in mean density on early–pruned tea (88.00 individuals/m²) than on late–pruned tea (67.67 individuals/m²) (LSD$_{0.05} = 6.80$) in the first three months, but was not different (52.17 vs 54.50 individuals/m², LSD$_{0.05} = 3.67$) between these treatments of pruning time in the following three months.

The ratio of _M. discolor_ to _T. aurantii_ in the first three months on early– and late–pruned tea was 1:18 and 1:62 respectively, of _M. sexmaculatus_ to _T. aurantii_ was 1:15 and 1:53 respectively, and in the following three months, the ratio of M. discolor to _T. aurantii_ was 1:16 and 1:37 respectively, and of _M. sexmaculatus_ to _T. aurantii_ was 1:14 and 1:39 respectively. The ratio of the group of coccinellids to _T. aurantii_ in the first three months on early and late pruned tea was 1:8 and 1:25 respectively, in the following three months was 1:7 and 1:17 respectively.

*Effect of time of tea pruning on relationship of predators with their prey (major pest insects)*

22
Table 3.24 . Effect of time of tea pruning on relationship of predators with their prey (major pests) in Phú Thọ in 2016

<table>
<thead>
<tr>
<th>No</th>
<th>Relationship of predatory insects with their prey</th>
<th>Correlation coefficient (R)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Early–pruned tea</td>
</tr>
<tr>
<td>1</td>
<td><em>O. sauteri</em> to <em>P. setiventris</em></td>
<td>-0.84</td>
</tr>
<tr>
<td>2</td>
<td><em>S. croceovittatus</em> to the group of tea lepidopterous pests</td>
<td>-0.95</td>
</tr>
<tr>
<td>3</td>
<td>Group of predatory heteropterans to <em>E. flavescens</em></td>
<td>-0.72</td>
</tr>
<tr>
<td>4</td>
<td><em>M. discolor</em> to <em>T. aurantii</em></td>
<td>-0.75</td>
</tr>
<tr>
<td>5</td>
<td><em>M. sexmaculatus</em> to <em>T. aurantii</em></td>
<td>-0.76</td>
</tr>
<tr>
<td>6</td>
<td>Group of coccinellids to <em>T. aurantii</em></td>
<td>-0.72</td>
</tr>
</tbody>
</table>

On early- and late- pruned tea, predatory insects also played varied roles in controlling tea pest populations. Correlations of predators to their prey (*O. sauteri* with *P. setiventris*, *S. croceovittatus* with the group of tea lepidopteran pests, the group of predatory heteropterans with *E. flavescens*, *M. discolor* with *T. aurantii*, *M. sexmaculatus* with *T. aurantii* and group of coccinellids with *T. aurantii*) were negative and strong to very strong on early pruned tea, while on late pruned tea, those correlations were weaker.

### 3.4.6. Effect of chemical insecticides

Predatory coccinellids on tea were found to decline quickly due to insecticide spraying. The population density after 5–10 days of spraying decreased to 5–20%.

The Mopride 20WP insecticide with the shortest persistence, compared to Victory 585 EC and Actador 100WP, is suitable for controlling tea aphids and safer to tea products.

**Conclusions and recommendation**

**Conclusions:**

1. In Phú Thọ, 56 insect species in three families, eight orders were identified as pests of tea. Among them, three pests, namely *Biston suppressaria* Guence, *Chalcocelis albigutata* Snellen and *Archips sp.* were recorded for the first time in this province. Three most common pests were *E. flavescens* with two population peaks a year (one in May, the other in September), *P. setiventris* with only one peak in August, and *T. aurantii* without any distinct peak.

2. In Phú Thọ, 51 predatory insect species in 15 families, 7 orders were collected on tea, including one new species, viz. *Polistes communalis* Nguyen, Vu & Carpenter, 2017, and four new provincial records (namely, *C. lividipennis* Reuter, *P. peramatus* Uhler, *A. spinidens* Fabricius, *O. sauteri* (Poppius)). Four predators, namely *S. croceovittatus*, *O. sauteri* (Poppius), *M. sexmaculatus* (Fabricius) and *M. discolor* (Fabricius) were recorded to be the most common on tea.

3. *S. croceovittatus* reached a population peak on tea in June, and then decreased gradually and dropped to the bottom in December. For *O. sauteri* its occurrence was year–round on tea, with one population peak in May, and the other in
October, while predatory heteropterans as a whole reached the peak during July-August. For predatory coccinelids, *M. discolor* occurred year-round on tea, with two population peaks a year, one in June, and the other in November, whereas for *M. sexmaculatus*, the population density was not high, but stable across months of survey, however slight higher during the end months of year. Coccinellids as a whole had a peak in September.

4. During three years of survey, *O. sauteri* was found to have negative, strong correlations (R ranging from -0.69 to -0.92) to *P. setiventris* during May to October, *S. croceovittatus* to have negative and strong correlations (R ranging from -0.62 to -0.89) to the lepidopterous pests during April to September, and predatory heteropterans as a whole to have very strong correlations to the *E. flavescens* (R ranging from -0.77 to -0.88). Negative and very strong correlations to *T. aurantii* were also recorded for *M. discolor* (R ranging from -0.81 to -0.93) and for *M. sexmaculatus* (R ranging from -0.81 to -0.92) during April to July.

5. Ecological factors including variety, shade tree, plucking technique, pruning technique, pruning time and insecticide affected on densities of pest and predatory insects on tea. The highest population densities of *O. sauteri, S. croceovittatus* were found on the tea variety “Trung Du”, thoroughly–plucked, well–cared, lightly–pruned tea. The mean density of *O. Sauteri* was higher on tree–shaded tea than on tree–unshaded tea but the mean density of *S. Croceovittatus* was the same. The highest population densities of *M. discolor, M. sexmaculatus* were found on the tea variety “LDP1”, “LDP2”, tree–shaded tea, thoroughly–plucked, lightly–pruned tea. The population densities of all were different in first 3 month of year but were same in next 3 month, on tea early–pruned and late–pruned.

6. Negative, strong to very strong correlations of *O. sauteri* to *P. setiventris, S. croceovittatus* to the group of lepidopterous pests, predatory heteropterans as a whole to *E. flavescens, M. discolor* to *T. aurantii, M. sexmaculatus* to *T. aurantii* and predatory coccinellids as a whole to *T. aurantii* were found on the tea varieties “LDP1”, “LDP2” and “TRI777”, on tree–shaded, well–cared, thoroughly–plucked, lightly–pruned, and early–pruned tea. On the contrary, weak correlations were found on tree–unshaded, poorly–cared, thirdly–plucked, deeply–pruned and late–pruned tea.

**Recommendation:**

For controlling tea pests, further studies of encouraging, rearing and supplemental releasing important natural enemies such as *O. sauteri, S. croceovittatus, M. discolor* and *M. sexmaculatus* are necessary.

**CONTRIBUTION OF THE THESIS**

There are 3 new insect pests recorded on tea crops in Phu Tho province. This study showed significantly the composition of predator species in Phu Tho province and recorded 5 new predators on tea crops in Vietnam; especially, of which a new species is recorded as *Polistes communalis* Nguyen, Vu & Carpenter, 2017.

This study firstly provided the scientific evidence on the interaction between predators and their major insect pests attacking on tea crops, also the impact of ecological parameters on this interaction. This research also distributed new scientific knowledge on population fluctuation of some major insect pests on tea crops.
List of publications relating the dissertation


