MINISTRY OF EDUCATION AND TRAINING

VIETNAM ACADEMY OF SCIENCE AND TECHNOLOGY

GRADUATE UNIVERSITY OF SCIENCE AND TECHNOLOGY

Bui Thi Quynh Hoa

RESEARCH ON THE COMPOSITION OF PREDATORY INSECTS ON SOME INDUSTRIAL CROPS IN THE CENTRAL HIGHLANDS, BIOLOGICAL, ECOLOGICAL CHARACTERISTICS OF TWO SPECIES *RHYNOCORIS FUSCIPES* AND *EUAGORAS PLAGIATUS*

SUMMARY OF DISSERTATION ON ENTOMOLOGY

Code: 9 42 01 06

Hanoi – 2024

This work was completed at: Graduate University of Science and Technology - Vietnam Academy of Science and Technology

Academic Title, Name of Supervisors:

1. Assoc. Prof. Dr. Nguyen Thi Phuong Lien
2. Prof. Dr. Truong Xuan Lam

Referee 1: Prof. Dr. LE NGOC ANH

Referee 2: Prof. Dr. TRAN NGOC LAN

Referee 3: Prof. Dr. TRAN ANH ĐUC

The Dissertation was defended before the Doctoral Examination Board of Graduate University of Science and Technology - Vietnam Academy of Science and Technology on..., at.....2024.

The Dissertation can be accessed from:

1. The library of Graduate University of Science andTechnology
2. The National Library of Viet Nam

LIST OF THE PUBLICATIONS RELATED TO THE DISSERTATION

1. Hoa Thi Quynh Bui, Ngat Thi Tran, Hakan Bozdoğan & Lien Thi Phuong Nguyen, 2020, Additional knowledge respecting taxonomy of the social wasp genus *Ropalidia* (Hymenoptera: Vespidae: Polistinae) from Vietnam, with new records of three species and an updated key to species, *Zootaxa*, 4722 (1), pp. 034-040.

2. Truong Xuan Lam, **Bui Thi Quynh Hoa**, Ha Ngoc Linh & Wanzhi Cai, 2020, A new species of the assassin bug genus *Rihirbus* (Hemiptera: Heteroptera: Reduviidae) from Vietnam, *Zootaxa*, 4780 (3), pp. 587-593.

3. **Bui Thi Quynh Hoa,** Truong Xuan Lam, Nguyen Thi Phuong Liên, 2020, Study on species composition of insect predators on coffee tree at some areas in Dak Lak provice, *Scientific report - 10th National Entomology Conference*, *Ha Noi,* Agricultural publish, pp. 31-37.

4. Mai Van Thai, Vu Thi Thuong, **Bui Thi Quynh Hoa**, Nguyen Thanh Manh, Nguyen Thi Phuong Lien, 2022, Notes on species of vespid wasps (Vespidae: Hymenoptera) in the Central Highland, Vietnam, *TNU Journal of Science and Technology*, 227 (05), pp. 268-276.

5. Hoa Thi Quynh Bui, Thai Van Mai, Lien Thi Phuong Nguyen, 2023, A new species of the paper wasp genus *Ropalidia* Guérin-Méneville, *plebeja* group (Hymenoptera, Vespidae, Polistinae), from Vietnam, *Journal of Hymenoptera*, 96, pp. 543-553.

GENERAL INFORMATION

1. The urgency of the dissertation

Coffee, pepper, cocoa... are groups of perennial crops with high economic value. In Vietnam, coffees contribute an important proportion to the country's annual export turnover as well as effectively participate in economic and social programs such as hunger eradication and poverty reduction, sedentary farming settlement, creating jobs for millions of workers in mountainous areas, including a part of ethnic minorities, especially in the Central Highlands. Coffee is one of the agricultural products that brings the main source of income for farmers in the Central Highlands, grown widely in the provinces of Dak Lak, Dak Nong, Gia Lai, Kon Tum... These are basalt red soil areas, fertile, with a thick arable layer, and it has a hot and humid climate, so it is very suitable for coffee growing. According to the General Statistics Office, as of the crop from 2019 to 2020, Dak Nong planted 135 thousand hectares of coffee; Gia Lai and Kon Tum with planted areas of 82.5 thousand hectares and 14 thousand hectares respectively. The entire region's output reached more than 1.66 million tons, with an average yield of 2.77 tons/ha, creating more than 1 million jobs and bringing more than 3.5 billion USD in income to the economy.

On the other hand, the big challenge for coffee growers in Vietnam in general and the Central Highlands provinces in particular is to ensure clean and safe product quality that meets the requirements of domestic users and exports to the foreign markets. Therefore, using biological measures to prevent pests on industrial crops, including coffee, is necessary.

Currently in Vietnam, most studies refer to the composition of predatory insects along with their biological and ecological characteristics on some crops, typically research on flies that eat aphids belonging to the order Diptera on cruciferous vegetables in Hanoi and Vinh Phuc. The Japanese red ladybug *Propylea japonica* and the six-striped ladybug *Menochilus sexmaculatus* belonging to the order Coleoptera have been bred and used to prevent aphids on 19 plant species in Tu Liem, Hanoi.

However, the research and use of predatory insects in biological control of industrial crop pests (coffee, pepper, cocoa...) has received very little attention and is complete about their role in exploiting or releasing into fields to prevent pests. Furthermore, taking advantage of insect predators on crops requires more in-depth, complete and systematic research on component species diversity, their biological and ecological characteristics, as well as techniques for breeding in large quantities to release into the field to promote their role, thereby serving as a basis for using predatory insects in biological measures to prevent pests on crops. Achieving this will create a scientific basis to protect, maintain and take advantage of predatory insects, so we conducted the project: "*Research on the composition of predatory insects on some industrial crops in the Central Highlands and biological, ecological characteristics of two species Rhynocoris fuscipes and Euagoras plagiatus*".

2. Objectives of the study

Determine the composition of predatory insects on some industrial crops in the Central Highlands, and provide some biological and ecological characteristics of two common predatory stink bug species *Rhyconoris fuscipes* (Fabricius) and *Euagoras plagiatus* (Burm) in the study area.

3. Scientific and practical basis of the thesis

** Scientific significance*

The study provides scientific data on the diversity of insect prey species on some industrial crops in the Central Highlands as well as the biological and morphological characteristics of two species of predatory stink bugs, *Rhyconoris fuscipes* (Fabricius) and *Euagoras plagiatus* (Burm) of the family Reduviidae and the influence of some ecological factors (windbreak forest belt, shaping measures and post-harvest pruning) on the density and relationship between predatory insects with prey (pests on coffee trees).

** Practical significance*

Assess the prevalence of predatory insects on some industrial crops in some Central Highlands provinces, document the biological and ecological characteristics of two species *Rhyconoris fuscipes* (Fabricius) and *Euagoras plagiatus* (Burm) is the scientific basis for protecting, breeding and using them as pest control agents on plants.

Chapter 1. SCIENTIFIC BASIS AND LITERATURE REVIEW

1.1. Scientific basis

Natural enemies of pests, including predatory insects, are considered one of the groups of arthropods with economic and scientific significance.

To date, there have been many studies on predatory insects that have mentioned morphological and biological characteristics, the influence of environmental factors on population growth, and he relationship between the density of common insect predators and their prey, the main pest species... which forms the basis for pest prevention measures.

Integrated pest management (IPM), which encourages the use of biological measures to control crop-damaging insects, has been applied relatively commonly on many crops, bringing certain achievements, including research projects on the application, breeding, and release of predatory stink bug species, taking advantage of them to prevent pests on cotton and jute crops. Breeding predatory insects for biological control has received attention to prevent some important pests on cotton and soybean plants in some northern provinces of Vietnam. However, on some industrial crops, data on the biology and ecology of some common predatory stink bug species, which are used as a basis for breeding and taking advantage of them as biological pest control agents is still missing.

In the Central Highlands, Dak Lak, Dak Nong, Gia Lai, and Kon Tum are the provinces with the largest coffee and pepper growing areas in the country. Currently, to prevent pests on coffee, pepper, etc., the use of chemical pesticides is unavoidable, greatly affecting beneficial insects, including predatory insects. Furthermore, maintaining and protecting groups of predatory insects and breeding some predatory species to biologically prevent pests on coffee and pepper plants... have not received adequate research attention.

To have a scientific basis for implementing biological measures to prevent pests on industrial crops (coffee, pepper...) in the Central Highlands, systematic research on the composition of predatory insects and biological and ecological characteristics of common species is necessary. This issues needs attention, which is also the basis for us to carry out this topic.

1.2. Overview of research on predatory insects in the world

1.2.1. Research on the composition of predatory insect in the world

There are many studies around the world on the species composition of predatory insects. For example, Christiane (2008) reports that there are more than 6,600 species of stink bugs belonging to the family Reduviidae described on the basis of analysis of morphological characteristics, of which the subfamily Hacpartorinae is the most diverse. According to Zhao et al. (2009) subfamily Harpactorinae has 300 genera with 2000 species of predatory stink bugs. Ghahari et al. (2013) identified 109 species and subspecies of stink bugs of the family Reduviidae belonging to 24 genera and seven subfamilies (Emesinae, Harpactorinae, Holoptilinae, Peiratinae, Phymatinae, Reduviinae and Stenopodainae).

Regarding predatory wasps, Pickett and Carpenter, (2010) listed the Vespidae family as having about 5000 species. The Vespidae family is widely distributed around the world and includes six subfamilies: Euparagiinae, Masarinae, Eumeninae, Stennogastrinae, Polistinae, Vespinae. Gess et al. (2014) in their 40-year study of honey bees and predatory wasps in southern Africa, counted 927 species. Among them, there are 504 species of wasps distributed in 18 families. Tan et al. (2018) listed 267 species and subspecies belonging to 51 genera from the subfamily Eumeninae (Vespidae) in China. The variety *Nortozumia* van der Vecht, 1937 was first recorded, and a classification key to species was also established.

For prey-catching beetles, Priyanka et al. (2020) announced 44 species with 22 genera of the Coccinellidae family in the Eastern Himalaya biodiversity hotspot, India. Mutin (2005) at the Third Conference, Japanese scientists collected and identified 630 species present in the islands and mainland of this country.

Research on other prey species includes Dmitry et al. (2019) identified 35 species of predatory flies belonging to 18 genera and insectivorous fly family Asilidae in Mordovia, Russia. Subramanian and Babu (2017) listed 488 species of dragonflies and 27 subspecies in 154 genera and 18 families of the order Odonata in India. According to Araujo and Pinto (2021) collected at Mananciais da Serra Reserve, Brazil, 84 species, 43 subspecies and nine families of dragonflies have been identified.

1.2.2. Studies on the biological characteristics of predatory insects around the world

The biological characteristics of predatory insects around the world have been studied by many scientists, mainly focusing on some orders such as Heteroptera by authors Uematse (2006), Srikumar et al. (2014), Abdul et al. (2018). Hymenoptera was studies by Ohl and Linde (2003), Christophe and James (2012), and Fateryga (2020). The Coleoptera was by some authors such as Mari et al. (2005), Zhang et al. (2012), and Nathália et al. (2021). The Diptera was studies by Pienda et al. (2007) and Kumari (2020).

1.2.3. Research on the relationship between predatory insects and prey

The relationship of some predatory insects such as ladybugs, stink bugs... with common pests as prey was studied by Chowdhury et al. (2008), Roy et al. (2010), Shahid et al. (2018), Tomson (2021).

1.3. Overview of research on predatory insects in Vietnam

1.3.1. Studies on the composition of predatory insects in Vietnam

In Vietnam, studies on the composition of insect predators on crop groups have been carried out for a long time, typically the research works of authors such as Vu Quang Con, Truong Xuan Lam (2001), Dang Duc Khuong (2005), Nguyen Thi Phuong Lien and Khuat Dang Long (2003), Pham Quynh Mai (2009), Nguyen Van Huynh and Phan Van Biet (2005), Pham Van Lam (2011), Phan Quoc Toan and Kompier Tom (2016).

1.3.2. Research on biological and ecological characteristics of predatory insects in Vietnam

In Vietnam, research on the biological and ecological characteristics of predatory insects is mainly carried out on subjects such as cruciferous vegetables, beans, cotton... and tested in the fields in the Northern provinces such as: *Andrallus spinidens*, *Sycanus croceovittatus*, *S. renewedi*, *Coranus fuscipennis* (family Reduviidae); Prey-catching lady beetles *Coccinella transversalis*, *Menochilus sexmaculatus*… (lady beetle family Coccinellidae) …

1.3.3. Studying the relationship of some predatory insects with prey

Research on the relationship of some common insect predators with their prey has mostly been carried out on the predatory stink bug *Coranus fuscipennis* whose prey are Lepidoptera pests; the ladybugs were Menochilus *sexmaculatus* Fabricius, *Propylea japonica* Thunberg, and *Lemnia biplagiata* Swartz with their prey being pests on cabbage, kohlrabi, mustard greens ...

1.4. Research on predatory insects in the Central Highlands

Research on the species composition and distribution of predatory insects in the Central Highlands is insignificant, mainly carried out in national parks and nature reserves. There are no scientific publications on the composition of predatory insects on industrial crops here.

*** General comments on research in Vietnam:**

In Vietnam, the results of research on predatory insects show that the majority of scientific publications are concentrated in the Northern and Central provinces. In the southern provinces and Central Highlands region, research is still very limited. The scientific data obtained during the research on the composition of insect prey species in the Central Highlands region is the data that helps to conduct more complete studies on the composition of insect prey species in Vietnam, especially species of the insectivorous stink bug family Reduviidae.

Research results on the biological and ecological characteristics of insects that prey on cruciferous vegetables, beans, cotton... have been published quite a lot. A number of predatory species have been studied for their biological and ecological characteristics and tested in fields in the Northern provinces to serve as a basis for breeding and using them in biological pest control. However, research on the biological and ecological characteristics of two predatory stink bug species, *Rhynocoris fuscipes* and *Euagoras plagiatus*, has not been conducted.

Chapter 2. LOCATION, CONTENT AND RESEARCH METHODS

2.1. Research time and location

Research period from 2018 to 2023.

Experimental research and investigation were conducted in the Central Highlands provinces such as Dak Lak, Dak Nong, Gia Lai, Kon Tum. Studies on some biological and ecological characteristics of two species *Rhynocoris fuscipes* and *Euagoras plagiatus* were conducted at the laboratory of Tay Nguyen University and at the Department of Insect Ecology, Institute of Ecology and Biological Resources, Vietnam Academy of Science and Technology. Investigation of density changes and relationships between predatory insects and prey were carried out on Coffee trees in Dak Lak.

2.2. Research subjects and tools

Research subjects: Predatory insects, with emphasis on species belonging to a number of families in the orders Heteroptera, Hymenoptera, Coleoptera, Mantoptera, Odonata and their prey such as pests that damage coffee, pepper...

Research tools: Insect nets, 90% alcohol, insect pin, cotton, camphor, magnifying glass, automatic thermometer and hygrometer, insect sample box, notebook to record survey data and experimental data, camera, stereo microscope, photoshop software...

2.3. Research content

1. Research on the composition of predatory insects on some crops (pepper, coffee...) at some research sites in the Central Highlands.

2. Study some morphological and biological characteristics of two common bug species, *Rhynocoris fuscipes* (Fabricius) and *Euagoras plagiatus* (Burm) in the study area.

3. Research the evolution of density, the relationship between predatory species and prey and the influence of some ecological factors on the density and relationship of predatory insects and their prey on coffee trees in Dak Lak.

2.4. Research methods

2.4.1. Investigating the composition of predatory insects and their prey: Methods used in studying the composition of predatory insects and prey using Plant Protection Institute (1997), Vitalis (1919), State Science Committee (1981)

2.4.2. Inspection and identification of research species: Identification of ladybug species using Hoang Duc Nhuan (2007), Truong Xuan Lam (2019), Nguyen Thi Phuong Lien 2020, Do Mnanh Cuong (2006), Ta Huy Thinh, (2010). Identification of prey using Plant Protection Institute (1976), Vitalis (1919), State Science Committee (1981).

2.4.3. Research on the morphological characteristics of two common predatory stink bug species: The external structural features and sizes of two predatory stink bug species are studied, described and drawn in egg, nymph and adult stages using Olympus SZX7 stereo magnifier. The described morphological characteristics include: color, morphological structure of the head, thorax and abdomen

2.4.4. Research on some biological characteristics of two common predatory stink bug species: Method to determine sexual development time and life cycle of predatory stink bugs raised in clean plastic boxes with diameter of 15-20cm and height 15-25cm (raising box), with moisturizing cotton. The prey animals used as food for predatory bugs are fed with *Tenebrio molitor* caterpillars, rice moth larvae of *Corcyra cephalonica* were raised in the laboratory with rice bran mixed with cornstarch. Termite species *Odontotermes subterranean* and a number of other prey collected from coffee and pepper plants and preserved and raised in the laboratory were also used.

2.4.5. Investigating the evolution of predatory insect density: The evolution of predatory insect density on coffee and pepper crops was investigated using the method in Plant Protection Institute (1997). The unit of calculation is prey/m^2

2.4.6. Studying the relationship between predatory insects and their prey: Researching the relationship between predatory insects and their prey through correlation coefficients divided into levels following Nguyen Ngoc Thua & Hoang Kien (1979).

2.4.7. Research on the effects of some ecological factors on predatory insects and their relationships with prey: Research on the effects of growing coffee with a windbreak forest belt, research on the effects of shaping and pruning techniques

2.5. Data processing method: The data are processed using Microsoft Office Excel 2013 software.

Chapter 3. RESEARCH RESULTS AND DISCUSSION

3.1. Composition of predatory insects and their prey on some crops in the Central Highlands

Results of investigating the composition of predatory insects in four Central Highlands provinces from 2018 to 2023 recorded 102 species belonging to 20 families in 05 orders. Among them, Hymenoptera has the largest number of species, with 39 species belonging to 25 genera and 5 families. Next is Heteroptera with 19 species belonging to 14 genera and 03 families. Coleoptera has 17 species belonging to 16 genera and 4 families. Next is the Odonata with 17 species belonging to 14 genera and 5 families. Finally, there is the Order Mantoptera with 09 species belonging to 9 genera and 3 families.

Among the total of 102 species of predatory insects recorded, there are two species newly described to science: *Rihirbus kronganaensis* Truong, Bui, Ha & Cai, 2020 and *Ropalidia daklak* Bui, Mai & Nguyen, 2020. One new record species for Vietnam is *Ropalidia binghami* van der Vecht, 1941.

Among the 102 species identified, there are 5 species that appear with a relatively common level (>50%), *Menochilus sexmaculatus* Fabricius, 1781; *Euagoras plagiatus* Burmeister, 1835; *Rhynocoris fuscipes* (Fabricius, 1787); *Sycanus fallen* Stål, 1863; *Delta pyriforme pyriforme* (Fabricius, 1775) and 36 species occur at a common level (21-50%).

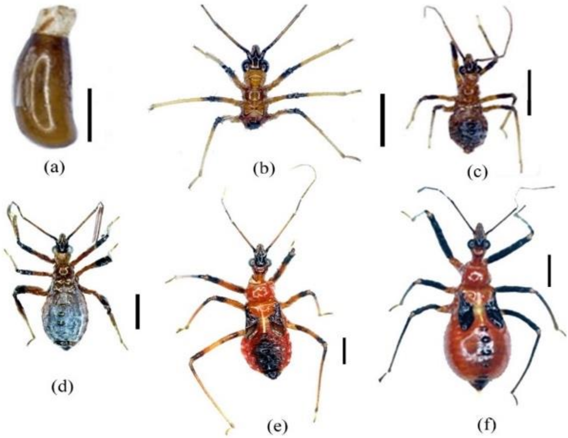
3.2. Research on some morphological and biological characteristics of two common stink bug species in the study area

3.2.1. Morphological characteristics of two common predatory stink bug species

3.2.1.1. Morphological characteristics of Rhynocoris fuscipes

Adult female *Rhynocoris fuscipes* have a body length ranging from 10.0 - 10.4mm. The head is red and has two pale markings near the eyes and the middle of the neck. The abdomen is bright red-brown. The nymphs of *R.*

fuscipes has 5 instars, light brown to dark brown, the head has no small streaks and no long lines along the body. The 1st and 2nd instar larvae have almost the same morphology. In the 2nd instar nymphs, the wing buds begin to differentiate and 2-3 dark brown spots appear. At the age of 3, the wing buds have appeared, and there are 3 large, clear, small pale-yellow spots on the upper abdomen. At age 4, the body has begun to gradually improve and the body of a 5-year-old larva has developed quite completely.

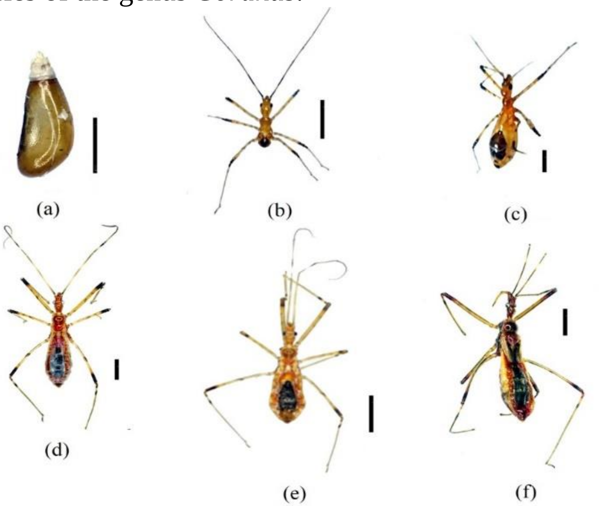


Figures 3.5. Morphological characteristics of eggs and larvae of *R. fuscipes*
(a). Egg, (b), Age 1, (c). Age 2, (d). Age 3, (e). Age 4, (f). Age 5.
Scale bar: 0.5 mm. (*Source: Bui Thi Quynh Hoa*)

Figures 3.6. Adult female of *Rhynocoris fuscipes*
(*Source: Bui Thi Quynh Hoa*)

3.2.1.2. Morphological characteristics of Euagoras plagiatus

Adult female of *Euagoras plagiatus has* a body length ranging from 9.0 - 9.6mm. The body is elongated, dark brown. The head is red and has a pale color near the eyes and the middle of the neck. The abdomen is light brown. The nymphs of *Euagoras plagiatus* has 5 instars, light brown to dark brown, and do not have long lines along the body like the heads of nymphs of other species of the genus *Coranus*.



Figures 3.7. Morphological characteristics of eggs and larvae of *E. plagiatus*
(a). Egg, (b). Age 1, (c). Age 2, (d). Age 3, (e). Age 4, (f). Age 5. Scale bar: 1.5 mm for a, b, c, d; 1 mm for e, f. (*Source: Bui Thi Quynh Hoa*)

Figure 3.8. Adult female of *Euagoras plagiatus* (*Bui Thi Quynh Hoa*)

The 1st and 2nd instar larvae have almost the same morphology, the 2nd instar wing buds begin to differentiate, and 2-3 brown spots begin to appear on the abdomen. At age 3, wing buds have appeared, and three large, clear light brown spots appear on the abdomen. At age 4, the nymph's body is close to that of an adult, with bright wing buds in the chest segment clearly visible. At age 5, the nymph's body has developed quite similar to that of an adult.

3.2.2. Biological characteristics of two common stink bug species in the study area

3.2.2.1. Biological characteristics of the predatory stink bug Rhynocoris fuscipes

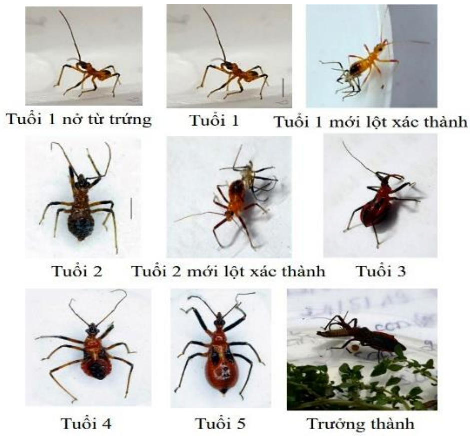


Figure 3.10. Instars of the predatory stink bug *R. fuscipes*
(*Source: Bui Thi Quynh Hoa*)

With temperature conditions of 25.5-29.3°C and humidity of 74.5-82.5%, the time to complete 1 life cycle of the predatory stink bug *Rhynocoris fuscipes* is from the time the female of the 1st generation lays eggs to ưhen females of the 2nd generation lay their first clutch of eggs, it ranges from 76-123 days (average 101.11 ± 6.18 days), in which the average development time in the egg stage ranges from 7-14 days (average 10.16 ± 0.75 days), the nymph period ranges from 53-86 days (average 72.91 ± 5.26 days) and the period from the last molt to the laying of the first egg ranged from 12 to 29 days (average 18.04 ± 1.27 days) (table 3.12).

Table 3.12. Life cycle development time of the predatory stink bug *Rhynocoris fuscipes*
(Temperature 25.5-29.3ºC, humidity 74.5-82.5%)

Experiment number		**Development time (day)**			
		Eggs (N=81-102)	**Whole juvenile stage** (N=35-45)	**Pre-mature** (N=10-15)	**Life cycle**
1	Ranging	8 - 14	53 - 79	18 - 24	79 - 117
	On average	10.86	71.05	18.07	99.98
2	Ranging	9 - 12	57 - 82	15 - 29	81 - 123
	On average	10.54	74.41	21.33	106.28
3	Ranging	7 - 11	57 - 86	12 - 16	76 - 113
	On average	9.08	73.26	14.73	97.07

In room conditions, when raising the predatory stink bug *Rhynocoris fuscipes* with rice moth *C. cephalonica* as food, the development time of the larvae of this species is in the F2 generation (average of whole stage 75,35 ± 4.28 days), 1-2 days longer than in the F1 generation (average 73.28 ± 3.52 days).

Table 3.13. Larval development time and survival rate of the predatory stink bug *R. fuscipes* with rice moth *C. cephalonica* as food over 2 generations

Number of experiment individuals	**Average development time ± SD of nymphs (days)**						**Survival rate (%)**
	Age 1	**Age 2**	**Age 3**	**Age 4**	**Age 5**	**Whole stage**	
F1 generation (N=35)	15,69 ± 0,14	14,94 ± 0,12	14,20 ± 0,10	13,65 ± 0,11	12,85 ± 0,08	73,28 ±3,52	84,90 ± 4,81
F2 generation (N=30)	17,25 ± 0,18	15,35 ± 0,13	15,02 ± 0,14	14,15 ± 0,12	13,58 ± 0,09	75,35 ±4,28	64,08 ±3,05

(*Note: N- number of stink bug individuals participating in the experiment*)

3.2.2.2. Biological characteristics of the predatory stink bug Euagoras plagiatus

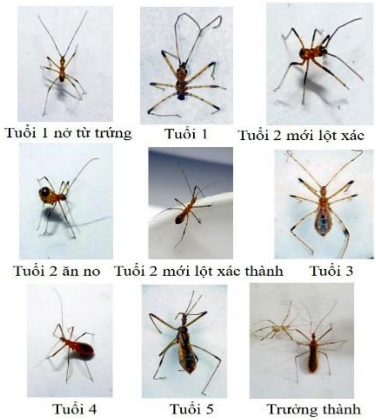


Figure 3.14. Different ages of nymphs of *E. plagiatus*

(Source: Bùi Thị Quỳnh Hoa)

The predatory stinkbug *Euagoras plagiatus* when kept in an experiment room at temperature condition of 25.5-29.3°C and humidity of 74.5-82.5%, showed the complete life cycle (from the time when the female of the first generation layed eggs to the time when the female of the second generation layed eggs) was about 106 days (59.72±3.65 days on average). Of which, the eggs developed from 3-8 days (5.53±0.32 days on average); the average development time of the whole juvenile stage (from age 1 to age 5) ranged from 53 to 86 days (40.89±2.58 on average days), and the period from the last molt to the laying of the first egg ranged from 8-17 days (13.30±1.26 days on average) (table 3.18).

Table 3.18. Life cycle of the predatory stinkbug *Euagoras plagiatus*

(Temperature of 25.5-29°C and humidity of 74.5-82.5%**)**

Experiment time		**Development time (days)**			
		Eggs (N=52-55)	**Whole juvenile stage** (N=36-43)	**Pre-mature** (N=15-20)	**Life cycle**
1	Ranging	4 - 8	53 - 79	10 - 16	67 - 103
	On average	6.08	39.19	13.2	58.47
2	Ranging	3 - 7	57 - 82	12 - 17	72 - 106

	On average	5.45	42.27	16.55	64.27
3	Ranging	3 - 6	57 - 86	8- 12	68 - 104
	On average	5.05	41.2	10.16	56.41
Ranging		3 - 8	53 - 86	8 - 17	67 - 106
On average		5.53 ± 0,32	40.89 ± 2,58	13.30 ± 1,26	59.72 ± 3,65

The results of rearing the predatory stinkbug Euagoras plagiatus with larvae of the rice moth *Corcyra cephalonica* show that: when feeding the predatory stinkbug *Euagoras plagiatus* with rice moth larvae *C. cephalonica* in the laboratory condition, the development time of the nymphs in the F2 generation (42.32 ± 2.01 days on average for whole stage) is not significantly different from that in the F1 generation (41 days on average), 23 ± 2.16 days) (Ftt=0.66 < Flt= 0.86). However, the development time of the nymphs fed with larvae of the rice moth *Corcyra cephalonica* in the F1 and F2 generations is significantly different (Ftt=0.22 > Flt=0.86) compared to the development time of the nymphs fed with mixture of different preys (*Tenebrio molitor* caterpillar, *Corcyra cephalonica* rice moth larvae, *Odontotermes* sp. termites). The survival rate in the raising process with rice moth food in the F2 generation is lower than that in the F1 generation (60.26 ± 2.88% on average) (table 3.19).

Table 3.19. Larval development time and survival rate of the predatory stinkbug *E. plagiatus* with rice moth *C. cephalonica* as food

Number of experiment individuals	**Average development time ± SD of nymphs (days)**						**Survival rate (%)**
	Age 1	**Age 2**	**Age 3**	**Age 4**	**Age 5**	**Whole stage**	
F1 generation (N=35)	5.64 ± 0.23	7.64 ± 0.35	8.30 ± 0.48	8.73 ± 0,38	10.95 ± 0.52	41.23 ± 2.16	84.64 ± 4.18
F2 generation (N=30)	5.81 ± 0.26	7.85 ± 0.30	8.67 ± 0,47	8.92 ± 0,41	11.35 ± 0.61	42.32 ± 2.01	60.26 ± 2.88

(Note: **N-** Number of experiment individuals*)*

3.3. Research on density changes, relationship between predators and prey and the influence of some ecological factors on density and relationships on coffee trees in Dak Lak

3.3.1. Density changes and relationship between predatory stinkbug species and preys (leaf-eating pests) in Dak Lak

The average density of predatory stinkbugs during two years (2019-2020) was 0.43 ± 0.05 ind/m^2. Of which, the density of the predatory stinkbug species *E. plagiatus* was 0.27 ± 0.03 ind./m^2 and *R. fuscipes* is 0.27 ± 0.03 ind/m^2.

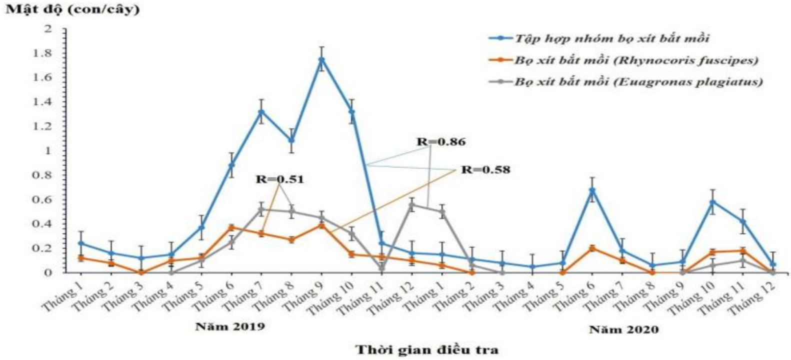


Figure 3.16. Density changes of a set of predatory stinkbug species, and two common predatory stinkbug species on coffee trees in Dak Lak

From July, the density of stinkbug populations increased by an average of 1.32 ind/m^2 (for all species), 0.32 ind/m^2 (for *E. plagiatus*) and 0.52 ind/m^2 (for *R. fuscipes*). The density of predatory stinkbugs was highest in September, on average 1.75 ind/m^2 (for all species), 0.45 ind/m^2 (for *E. plagiatus*) and 0.39 ind/m^2 (for *R. fuscipes*).

The set of predatory stinkbug species had a great, negative correlation with the leaf-eating pests (R=-0.69) from June to October 2019. They played a role in inhibiting leaf-eating pests on coffee trees. From November 2019 to December 2020, predatory bugs had very little role in restraining the caterpillar group (*Orvasca* sp., *Orgyia* sp. and *Cricula* sp).

The relationship between the two predatory stinkbug species (*E. plagiatus* and *R. fuscipes*) with their preys on coffee plants, which was a group of leaf-eating pests, also showed that it was similar to the set of predatory stinkbug species. The relationship between the two predatory stinkbug species and the leaf-eating pests on coffee plants also showed different correlation coefficients: negative, strong correlation from June 2019 to December 2019 (R=-66) and weak, positive correlation from January to May 2019 (R=0.24) and very weak negative correlation from January to December 2020 (R=-0.14) (figure 3.18).

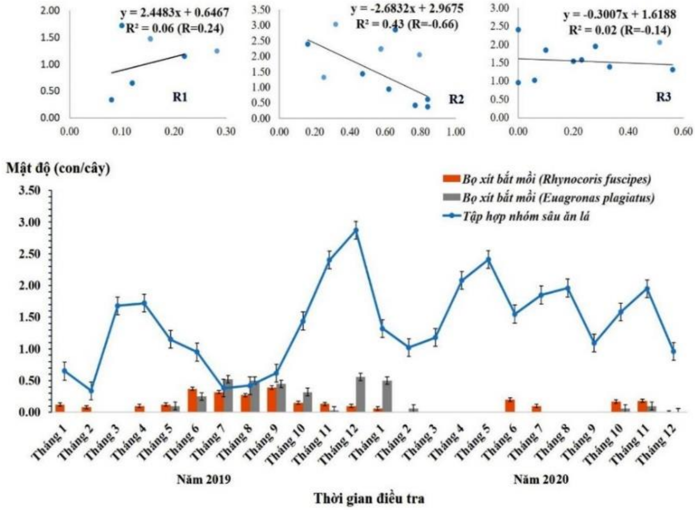


Figure 3.18. The relationship between the predatory stinkbugs *R. fuscipes* and *E. plagiatus* with their preys on coffee trees in Dak Lak

3.3.2. Quantity changes and relationships between predatory ladybug species on coffee trees in Dak Lak

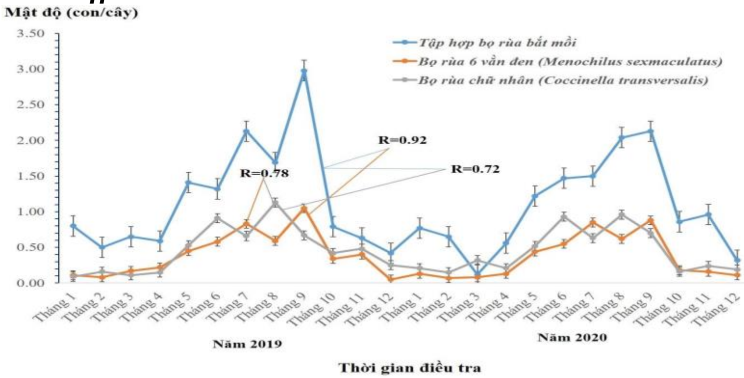


Figure 3.19. Density evolution and relationship of a collection of predatory ladybug species with two common predatory ladybug species on coffee trees in Dak Lak

The average density of predatory ladybugs during the 2 years (2019-2020) was 1.10 ± 0.14 ind./m2. The average density of *M. sexmaculatus* and *C. transversalis* was 0.38 ± 0.04 ind./m^2 and 0.45 ± 0.06 ind./m^2, respectively.

The assemblage of predatory ladybug species was negatively correlated at different levels with harmful aphids (*Pseudaulacaspis* spp. and *Aphis* spp.) in both study years. Specifically, the negative correlation was very tight (R=-0.74) from January to September 2019, relatively tight (R=-0.59) from October 2019 to March 2020. During that time, the population density of prey-catching ladybugs was high which caused to significantly reduce the density of prey (coffee aphids) from a maximum of 21.92 - 22.48/branch to 5.56. child/branch. During the period from April to December 2020, the set of predatory ladybug species had a weak, negative correlation with harmful aphids (R=-0.45).

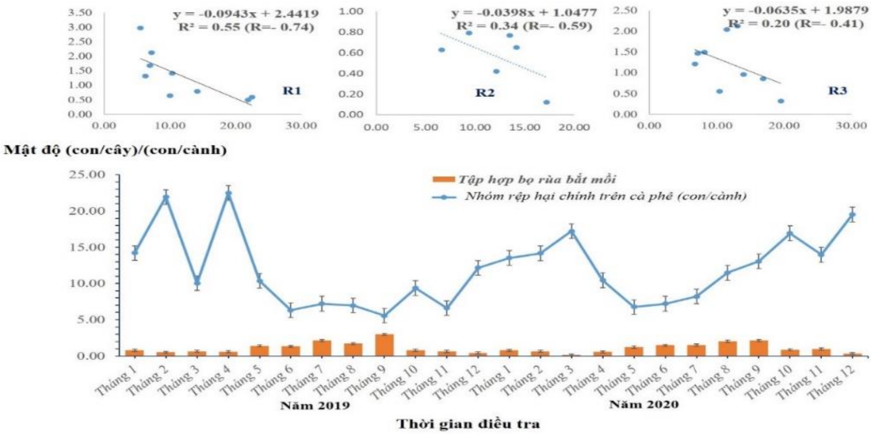


Figure 3.20. The relationship between the set of predatory ladybug species and their preys (aphid group) on coffee trees in Dak Lak

3.3.3. The influence of some ecological factors on the density and relationship between some insect predators and their preys on coffee trees in Dak Lak

3.3.3.1. Research on the effects of coffee planting with a wind-protected forest belt on the density and relationship between some insect predators and their preys.

The effect of the wind-protected forest belt on predatory ladybugs and harmful aphids on coffee trees caused differences not only in density but also in a ratio of the number of predatory ladybugs. The ratio of the number of ladybugs *Coccinella transversalis*: harmful aphids on coffee trees with a wind-protected forest belt is 1:51 and on coffee trees without a wind-protected forest belt was 1:46. The ratio of the assemblage of ladybugs: harmful aphids on coffee with a wind-protected forest belt was 1:27 and on coffee trees without a wind-protected forest belt was 1:25.

Table 3.22. The effect of wind-protected forest belt on the density of some insect predators and preys on coffee trees in Dak Lak

Predators/Preys	Surveying formula	Density (ind./m^2) in surveying months in 2019					Average density
		June	July	August	Sept	Oct	
Two common predatory stickbugs, *R. fuscipes* and *E. plagiatus* (ind/m^2)	ĐRCG	1.06	1.13	0.75	1.18	1.16	1.12a
	KĐRCG	0.62	0.84	0.77	0.84	0.47	0.71b
	LSD0,05						0.7
Leaf-eating pests (larvae of *Cephonodes* sp., caterpillars of *Orvasca* sp., caterpillars of *Biston* sp., ladybugs of *Thosea* sp. and spider beetles of *Parasa* sp.) (ind/m^2)	ĐRCG	1.36	1.88	3.08	2.69	3.14	2.63a
	KĐRCG	1.43	3.81	3.14	2.24	3.11	2.55a
	LSD0,05						0.91
Ratio of two common predatory stickbugs and leaf-eating pests	ĐRCG	1:2					
	KĐRCG	1:2					
The assemblages of predatory sitckbugs (ind/m^2)	ĐRCG	1.28	1.26	2.44	1.64	2.02	1.93a
	KĐRCG	0.88	1.32	1.08	1.75	1.32	1.27b
	LSD0,05						0.11
Leaf-eating pests (larvae of *Cephonodes* sp., caterpillars of *Orvasca* sp., caterpillars of *Biston* sp., ladybugs of *Thosea* sp. and spider beetles of *Parasa* sp.) (ind./m^2)	ĐRCG	1.84	2.36	3.20	5.84	6.93	4.03a
	KĐRCG	2.35	2.60	2.90	6.30	6.85	4.20a
	LSD0,05						3.41

Ratio of the assemblage of predatory stickbugs and leaf-eating pests	ĐRCG	1:32					
	KĐRCG	1:36					
Predatory ladybug *C. transversas* (ind./m^2)	ĐRCG	1.27	1.56	0.66	1.31	1.27	1.21a
	KĐRCG	0.91	0.66	1.13	0.67	0.42	0.76b
	LSD0,05						0.14
Main harmful aphids on coffee trees (*Coccus* sp. scale aphid, *Saissetia* sp. scale aphid, *Pseudococcus* sp. mealybug)	ĐRCG	2.42	1.93	2.51	3.12	3.17	2.63a
	KĐRCG	1.32	2.13	1.69	2.98	0.79	1.78b
	LSD0,05						0.24
	ĐRCG	7.23	6.89	7.69	5.65	10.03	7.49a
	KĐRCG	6.32	7.20	6.96	5.56	9.36	7.08b
	LSD0,05						2.11
The ratio of the number of ladybugs *Coccinella transversalis* and harmful aphids	*ĐRCG*	1:51					
	KĐRCG	1:46					
The ratio of the assemblage of ladybugs and harmful aphids	ĐRCG	1:27					
	KĐRCG	1:25					

Notes: ĐRCG – with wind-protected forest belt, KĐRCG - without wind-protected forest belt.

Numbers shows difference with P=0.05 (ANOVA analysis)

3.3.3.2. Effects of post-harvest shaping and pruning on the density and relationship between some insect predators and preys on coffee trees

The density of two predatory stinkbug species, *R. fuscipes* and *E. plagiatus*, on coffee trees with PP1 (1.16 ind./m^2) is higher than that on coffee plants with PP2 (0.65 ind./m^2). The average density of predatory bugs over 6 monitoring months on coffee trees with PP1 was 1.26 ind./m^2, higher than that on coffee trees with PP2 (0.78 ind./m^2). Meanwhile, the density of leaf-eating worms in PP1 and PP2 was 13.22 ind./m^2 and 14.94 ind./m^2, respectively (not significantly different).

The average density of ladybug *C. transversalis* over 6 monitoring months in the PP1 formula was 1.33 ind./m^2, higher than that in the formula without wind-protected forest belt (1.08 ind./m^2). Meanwhile, the density of the main harmful aphids (*Coccus* sp. scale aphid, *Saissetia* sp. scale aphid, *Pseudococcus* sp. mealybug), had a difference between PP1 and PP2. Specifically, the average density of harmful aphids to over 6 monitoring months on coffee trees with PP1 was 23.05 ind./m^2, higher than that in formula PP2 (ind./m^2).

Table 3.25. The effects of shaping and pruntintg techniques on the density of predatory insects and their preys on coffee plants in Dak Lak in 2020

Predators/Preys	**Surveying formula**	**Density (ind./m^2) in surveying months in 2020**						**Predators/ Preys**
		Jan	**Feb**	**Mar**	**Apr**	**May**	**Jun**	
Two common predatory stickbugs, *R. fuscipes* and *E. plagiatus* (ind./m^2)	PP1	1.56	1.48	1.40	0.50	0.60	1.40	1.16^a
	PP2	0.87	0.81	0.55	0.23	0.19	1.24	0.65^b
	LSD0.05							0.1
Leaf-eating pests (larvae of *Cephonodes* sp., caterpillars of *Orvasca* sp., caterpillars of *Biston* sp., ladybugs of *Thosea* sp. and spider beetles of *Parasa* sp.) (ind./m^2)	PP1	8.4	9.5	12.6	18.5	17.7	16.2	13.8^a
	PP2	2.1	7.5	10.0	15.2	12.4	10.5	10.3^b
	LSD0.05							0.25
The assemblages of predatory sitckbugs (ind./m^2)	PP1	1.15	1.29	1.15	1.48	1.03	1.45	1.26^b
	PP2	0.42	0.62	0.62	0.94	0.65	1.43	0.78^a
	LSD0.05							0.21

Leaf-eating pests (larvae of *Cephonodes* sp., caterpillars of *Orvasca* sp., caterpillars of *Biston* sp., ladybugs of *Thosea* sp. and spider beetles of *Parasa* sp.) (ind./m^2)	PP1	4.48	16.84	19.8	12.4	11.4	14.4	13.22^a
	PP2	8.36	13.16	15.4	18.08	15.4	19.25	14.94^a
	LSD0.05							1.02
Predatory ladybug *C. transversas* (ind./m^2)	PP1	1.60	1.30	0.53	1.17	1.71	1.68	1.33^a
	PP2	0.56	1.20	0.52	1.07	1.00	2.13	1.08^b
	LSD0.05							0.07
The assemblage of ladybug species (ind./m^2)	PP1	1.39	1.73	1.37	1.74	2.82	2.82	1.98^a
	PP2	0.39	0.73	1.37	0.74	0.82	1.82	0.98^b
	LSD0.05							0.22
Main harmful aphids on coffee trees (*Coccus* sp. scale aphid, *Saissetia* sp. scale aphid, *Pseudococcus* sp. mealybug)	PP1	24.2	28.5	28.2	16.2	19.5	21.7	23.05^a
	PP2	9.00	14.2	28.4	12.2	8.2	7.5	13.32^b
	LSD0.05							0.18

Considering 4 pairs of predatory insects and main pests on coffee trees in formulas PP1 and PP2, it showed that: the relationships between the predatory bugs *Rhynocoris fuscipes* and *Euagoras plagiatus* and the group of leaf-eating pests (larvae of *Cephonodes* sp., caterpillars of *Orvasca* sp., caterpillars of *Biston* sp., ladybugs of *Thosea* sp. and spider beetles of *Parasa* sp.), between a set of preying bugs and leaf-eating caterpillars, between ladybug *Coccinella transversalis* and the main harmful aphids (*Coccus* sp. scale aphid, *Saissetia* sp. scale aphid, *Pseudococcus* sp., mealybug), the assemblage of predatory ladybugs and main harmful aphid groups had a strong, negative correlation in formular PP1, but weaker, negative correlation in formular PP2.

CONCLUSION AND RECOMMENDATION

CONCLUSION

1. Investigation on coffee and some other industrial crops in 4 provinces in Highlands (Dak Lak, Dak Nong, Gia Lai and Kon Tum), recorded 102 species belonging to 07 orders and 23 families. Two species, *Rihirbus kronganaensis* Truong, Bui, Ha & Cai, 2020 and *Ropalidia daklak* Bui, Mai & Nguyen, 2020 were described new to science. The species, *Ropalidia binghami* van der Vecht, 1941 was recorded as new to Vietnam fauna.

2. Under the condition of temperature of 25.5-29.3℃, humidity of 74.5-82.5%, and being fed with *Tenebrio molitor*, rice moth larvae *Corcyra cephalonica*, termites *Odontotermes* sp., the life cycle development time of the predatory stinkbug *Rhynocoris fuscipes* ranged from 76-123 days (101.11 ± 6.18 days on average), of which the egg stage ranged from 7-14 days (10.16 ± 0.75 days on average) the nymph stage ranged from 53-86 days (72.91 ± 5.26 days on average) and the pre-oviposition stage ranged from 12-29 days (18.04 ± 1.27 days on average). The complete life cycle of the predatory stinkbug *Euagoras plagiatus* ranged from 67-106 days (59.72 ± 3.65 days on average), in which egg development stage was from 3 - 8 days (5.53 ± 0.32 days on average), the nymph development stage ranged from 29-53 days (40.89 ± 2.58 days on average) and the pre-oviposition stage ranged from 8-17 days (13.30 ± 1.26 days on average).

3. During 2 years of investigation, the average density of the predatory stinkbug population was 0.43 ± 0.05 ind./m^2, the predatory stinkbug *E. plagiatus* was 0.27 ± 0.03 ind./m^2 and *R. fuscipes* is 0.27 ± 0.03 ind./m^2. The average population density of all prey-catching lady beetles was 1.10 ± 0.14 ind./m^2, the average density of the predatory ladybug *M. sexmaculatus* was 0.38 ± 0.04 ind./m^2 and the average density of the species *C. transversalis* was 0.45±0.06 ind./m^2. The densities of two common predatory stinkbugs (*E. plagiatus* and *R. fuscipes*) and common predatory lady beetles (*M. sexmaculatus* and *C. transversalis*) were closely related to the assemblages of predatory stinkbugs and a collection of predatory ladybugs.

4. The collection of stinkbugs had a peak from July to October 2019 and was low in the remaining months. The collection of catching-prey ladybugs

had a peak from May to September 2019 and was low in the remaining months. From June to October 2019, the collection of stinkbug species had the negative and tight correlation (R=-0.69) with leaf-eating pests on coffee trees. From May to September 2019, the collection of predatory ladybugs had a strong and negative correlation (R=-0.74) with the main harmful aphids on coffee trees. The tight, negative correlation presented the role of stinkbugs and predatory ladybugs in inhibiting leaf-eating pests and aphids, respectively.

5. The density of the predatory bug assemblages, of *R. fuscipes* and of *E. plagiatus* on coffee trees with wind-protected forest belts and coffee trees using shaping and pruning techniques were all higher than that on coffee trees without wind-protected forest belts and on multi-stem coffee trees without stopping the top. The density of predatory stinkbug populations, of *R. fuscipes* and of *E. plagiatus*, all played a role in inhibiting the population of leaf-eating pests on coffee trees with wind-protected forest belts and coffee trees using the shaping and pruning technique. It was shown by a relatively close correlation compared to that on coffee trees without a wind-protected forest belt and on multi-stem coffee trees without stopping the top.

6. The density of prey-catching lady beetles and of the ladybug species *C. transversalis* on coffee trees with a wind-protected forest belt and coffee trees with shaping and pruning techniques were all higher than that on coffee trees without wind-protected forest belt and on multi-stem coffee trees without stopping the top. The predatory ladybug assemblages, ladybug species *C. transversalis*, played a role in inhibiting the number of the main harmful aphids. On coffee trees with a wind-protected forest belt and coffee trees with shaping and pruning techniques showed a relatively tight correlation in comparison with on coffee trees without a wind-protected forest belt and on multi-stem coffee trees without stopping the top.

RECOMMENDATIONS

1. It is necessary to have measures to protect and take advantage of predatory insects in controlling industrial crop pests in the Central Highlands, especially predatory bugs, predatory bees and predatory beetles.

2. There needs to be a follow-up study on the breeding and release of two common stinkbug species, *Rhynocoris fuscipes* and *Euagoras plagiatus*, to take advantage of these two species in preventing leaf-eating pests on industrial crops, especially on coffee plants in the Central Highlands provinces.

NEW CONTRIBITUON OF THE DISSERTATION

1. It is first time that a systematic list of predatory insects in some Central Highlands provinces was presented. Two new species, *Rihirbus kronganaensis* species Truong, Bui, Ha & Cai, 2020 and *Ropalidia daklak* Bui, Mai & Nguyen, 2020 were described and a new country record was also documented.
2. It is first time that new data on the biological and ecological characteristics of two predatory stinkbug species, *Rhyconoris fuscipes* (Fabricius) and *Euagoras plagiatus* (Burm) was provided.
3. Some new data on the changes in individual numbers and relationships between some predatory insect species and their preys was added; the effects of wind-protected forest belts and shaped and pruned coffee trees on the density and relationship between predatory stinkbugs, predatory ladybugs and their prey on coffee trees were also provided for the first time.