Population Dynamics and Prey Composition of *Tetragnatha* Spider in Semi-Organic Rice Field of Ranot District, Songkhla Province, Southern Thailand

Venus Saksongmuang

A Thesis Submitted in Partial Fulfillment of the Requirements for the Degree of Master of Science in Ecology (International Program)

Prince of Songkla University

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Major Program	Ecology (International Program)

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I hereby certify that this work has not been accepted in substance for any degree, and is not being currently submitted in candidature for any degree.

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ชื่อวิทยานิพนธ์ การเปลี่ยนแปลงประชากรและองค์ประกอบเหยื่อของแมงมุมเขี้ยวยาว สกุล *Tetragnatha* ในนาข้าวกึ่งอินทรีย์ อำเภอระโนด จังหวัดสงขลา ภาคใต้ของประเทศไทย

ผู้เขียน นางสาววีนัส ศักดิ์สองเมือง

สาขาวิชา นิเวศวิทยา (นานาชาติ)

ปีการศึกษา 2560

บทคัดย่อ

แมงมุมเขี้ยวยาว สกุล *Tetragnatha* เป็นผู้ล่าที่พบได้ทั่วไปในระบบนิเวศนาข้าว กินแมลงหลากหลายชนิดเป็นอาหาร อย่างไรก็ตามการศึกษาการเปลี่ยนแปลงประชากรแมงมุมตามระยะการเจริญเติบโตของข้าวยังถือเป็นที่เข้าใจกันไม่มากนัก ดังนั้นการศึกษาครั้งนี้ ได้ทำการประเมินการเปลี่ยนแปลงประชากรและองค์ประกอบเหยื่อของแมงมุมเขี้ยวยาว สกุล *Tetragnatha* ในพื้นที่นาข้าวแบบกึ่งอินทรีย์ อำเภอระโนด จังหวัดสงขลา ตลอดระยะการเจริญเติบโตของข้าว 4 ระยะ ได้แก่ ระยะแตกกอ ระยะตั้งท้อง ระยะออกรวงและระยะหลังเก็บเกี่ยว ซึ่งทำการเก็บตัวอย่างแมงมุมและแมลงในช่วงเวลา 19.00-22.00 น. เนื่องจากเป็นช่วงเวลาที่แมงมุมสกุล *Tetragnatha* ทำกิจกรรมสูงที่สุด จากการศึกษาพบว่าจำนวนชนิดและความชุกชุมของแมงมุมสกุล *Tetragnatha* ในระยะข้าวตั้งท้องมีค่าสูงกว่าระยะอื่นๆอย่างมีนัยสำคัญ และพบว่าเหยื่อกลุ่มหลักของแมงมุมมีความแตกต่างกันระหว่างระยะการเจริญเติบโตของข้าว ซึ่งแมลงในวงศ์ Chironomidae และ Corixidae เป็นเหยื่อกลุ่มหลักที่พบได้ในระยะข้าวแตกกอและตั้งท้อง หลังจากนั้นกลุ่มเหยื่อจะเปลี่ยนเป็น Delphacidae ซึ่งสามารถตีความได้ว่าแมลงที่มีโครงสร้างร่างกายอ่อน รยางค์ขาและปีกยาวและทำกิจกรรมในช่วงเวลาเดียวกันกับการสร้างใยของแมงมุม มีแนวโน้มที่จะติดใยแมงมุมได้ง่ายกว่าแมลงกลุ่มอื่นๆ จากการศึกษาครั้งนี้สรุปได้ว่า การเปลี่ยนแปลงประชากรแมงมุมและองค์ประกอบเหยื่อของแมงมุมได้รับผลมาจากระยะการเจริญเติบโตของข้าวซึ่งส่งผลให้แหล่งอาหารและแหล่งที่อยู่อาศัยแตกต่างกันในแต่ละระยะการเจริญเติบโตของข้าว

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ABSTRACT

Tetragnatha spiders are common predators in rice field ecosystems, which feed on various kinds of insects, but their population dynamics with the progress of rice growing stages are poorly understood. This study assessed the population dynamics and prey composition of *Tetragnatha* spiders in semi-organic rice fields in southern Thailand during four stages of rice plants, including vegetative growth stage, reproductive stage, ripening stage, and after harvesting stage. Spider and insect sampling was conducted at night between 1900h to 2200h because feeding activity of *Tetragnatha* spiders is highest. The results showed that species richness and abundance of *Tetragnatha* spiders were significantly higher in the reproductive stage than in the other stages. The main prey families captured by *Tetragnatha* spiders were different among stages of rice plants. Chironomidae, Corixidae and Baetidae were the main prey in the vegetative growth and the reproductive stages, while they were changed to Delphacidae thereafter. Insects with soft body and have high activity in the same period with building web of *Tetragnatha* spider tended to be caught in the web easily. It is concluded that both the spider populations and prey compositions are influenced by the stage of rice plants, which provided different food and habitat availability for spiders in rice ecosystems.

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Venus Saksongmuang

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CHAPTER 1

INTRODUCTION

1.1 General introduction

Predator-prey interaction is a class of ecological interaction in which one species gets benefit (predator) while another species is harmed (prey). Predators play an important role in ecosystem by controlling the number of prey and limiting growth rate of prey population (Nyffeler, 2000). In natural or agricultural ecosystem, Researchers concern about potential predator and their population dynamics in order to sustain their population densities at suitable levels for maintaining their prey at low equilibrium (Hassel, 1978). This concept is applied for agricultural management which require to use predator as a natural enemy to regulate pest population.

Tetragnatha spider is a dominant group of predator found in agricultural areas, especially in rice ecosystem. Previous studies showed that some species of *Tetragnatha* spider can regulate rice insect pest. For example, Mathirajan (2001) found that *Tetragnatha javanas* effectively reduced the population of Green leafhoppers and Brown planthoppers. Tahir *et.al.* (2009) showed that main prey trapped in the webs of *T. javana* were Lepidoptera, Diptera, Homoptera, Coleoptera, Hymenoptera and Orthoptera. Moreover, Butt (2010) reported that *T. javana* was high density in milking stage of rice (immature stage before ripening of the fruit). According to Tsutsui *et al.* (2016) who found that *Tetragnatha* spiders performed spatial and temporal dynamics in environmentally friendly paddy fields.

However, many previous studies concerning spider populations and their prey were conducted in only a particular stage of rice plants (Wang et al. 2004; Tahir et al. 2009; Tsutsui et al. 2016), and only one covered all the stages of rice plants (Butt et al. 2010). Here, I examined the population changes, prey compositions and prey availability of *Tetragnatha* spiders in all stages of rice plants along the rice growing season in semi-organic rice field of southern Thailand. I expect that population dynamics and prey utilization patterns of *Tetragnatha* spiders are closely associated with the progress of rice growing stages *via* temporal changes in potential prey and habitat structure.

1.2 Literature reviews

1.2.1 Spider in rice field

Spider is small group of arthropod in class Arachnida, order Araneae. Spiders are dominant predator in terrestrial ecosystem. Most of them are insectivorous. They can feed on various kinds of prey and may also against broader range of prey type. So, the important role of spiders is to regulate the insect population because they are generalist predators of insect, exhibit a high level of diversity in ecosystem and serve as a buffer to limits the population growth of prey (Nyffeler, 2000; Venturino, *et al*., 2008; Chatterjee *et al.*, 2009).

Spider have different predatory strategies, some spiders walk for searching prey such as wolf spider, some run or jump for catching prey like jumping spider and some build webs to trap insects as web-building spider (Herberstein, 2011). They use venom to subdue their prey and most spider venom paralyzes the prey before eating. Moreover, unique predatory characters of spider are wasteful killing or partial consumption of prey by hunting spider (Samu and Biro, 1993) and mortality of non-consumed prey by web-building spider (Sunderland, 1999)

1.2.2 Spider in family Tetragnathidae (Long-jawed spider)

The orb-weaving spider family Tetragnathidae is the dominant group in rice field, currently includes 48 genera and 988 species worldwide (World Spider Catalog, 2017).

Biology: They range in size from 2-23 mm. Many species build horizontal orb webs with an open hub. Most of them are found near water or in meadows, marshes, woodland and wetland edges. These spiders always sit and wait their prey in the center of web. When they are disturbed, they will drop down to the ground or hang on the vegetation. Adapting to the vegetation by stretching out their long legs for making themselves undistinguished.

Characters of family: Many genera of spiders in this family are usually elongated spiders, legs and chelicerae are very long. However, there are some genera with oval/round abdomens or normal sized chelicerae. Males are usually smaller than females with the swollen abdomen at the base. The eyes are sub-equal and arranged in 2 rows of 4 usually with the medial eyes closer to each other than to the lateral eyes. The legs are long and slender and mostly with spines but in some genera there are non. Color quite varies with green, yellow, bright white and red, and often with copper or silver papilla (Lissner, 2011).

Foraging strategy: All of Tetragnathidae spider are web-building spider, so their feeding strategy is sit-and wait strategy. This is stationary way; spider sit on web waiting for their prey to come to their web. The requirement for sit-and wait strategy of web-building spider is a food that moves. Because most of web spiders spin aerial webs which filter the aerial plankton (Turnbull, 1973; Chacon and Eberhard, 1980). The population of web building spiders generally depend on a high number of prey availability in a particular environment.

1.2.3 Spider in genus *Tetragnatha*

Spider genus *Tetragnatha* currently includes 347 species in the world (World Spider Catalog, 2017). *Tetragnatha* is common and dominantn orb-weaving spider genus in the world. This genus can live in tropical zone, temperate zone, arctic zone and on all continents (except Antarctica) (Aiken and Coyle, 2000).

Tetragnatha size varies between 5 and 15 mm. Most are greatly elongated spiders with very thin and long legs. Abdomen long and narrow, more than twice as long as wide. The chelicerae (jaws) are very long and great size (Figure 1). The jaws together with the two long palps it appears as they have four jaws. Males have a strong projecting spur on anterior surface which often project in forward in a horizontal position (Ovtsharenko and Tanasevitch, 2002).

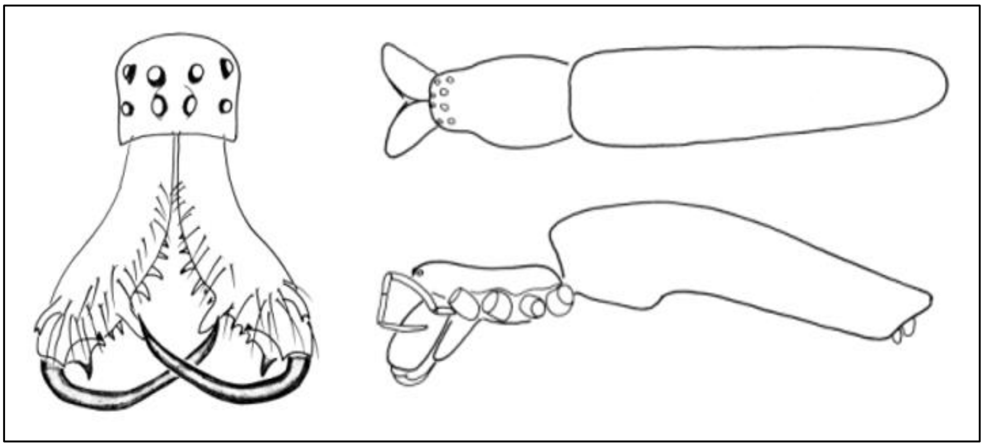

Figure 1 *Tetragnatha* spider morphology from front view, top view and side view

Tetragnatha species build a small roughly circular web with an open center in shrubs, especially near water courses. When the spiders are not in the web they rest stretched out in front and behind along a twig or branch or grass leave. If spiders are disturbed, they usually drop to the ground. Most of them always build webs at night and feed on insects that were caught on web (Nieuwenhuys, 2008) (Figure 2).

Figure 2 Web structure of *Tetragnatha* spider and its behavior when it is not in the web (Dimitrov and Hormiga, 2009)

Foraging strategies: *Tetragnatha* species are nocturnal spider, they built their horizontal webs among plants in the early evening and required around an hour to complete a web, which slightly different between each species in height, diameter, and capture area (Tahir *et al*., 2009). *Tetragnatha* species make webs with an open hub to adapt for capturing small prey flying weakly.

Kiritani *et.al*. (1972) evaluated spider predation on green rice leafhopper and they found that predation by female of *Tetragnatha* on leafhoppers in rice field made up 44 per cent of its diet and more than half of food items of *Tetragnatha* spp. consisted of flying-insects, such as adult hoppers, mosquitoes and midges. Yoshida (1987) reported that *Tetragnatha praedonia* captured mainly small Diptera (especially midge flies), and a few large preys was captured by the web and suggested that it does not adapt to capture large prey. The foraging strategies and diet composition of *Tetragnatha javana* was studied in rice ecosystems and the result showed that the highest feeding activity of *T. javana* was between 19:00 h to 21:00 h and gently decreased after that until 02:00 h. Main prey orders trapped in the webs were Lepidoptera, Diptera, Homoptera, Coleoptera, Hymenoptera, Orthoptera, and Araneae, respectively (Tahir *et al*. 2009).

1.2.4 Rice ecosystem/ rice field

Rice field is a manmade ecosystem which developed mostly from converted swamp or flooded lowland. It sustains a monocrop of rice; *Oryza sativa*. The rice fields are flooded, drained and subjected to a variety of agricultural practices essential for the management of the crop. The rice fields remain relatively stable on a short period during a single growing season but extremely unstable on the long term. Thus the rice ecosystem was surrounded by a variety of habitats that are temporary and undergo rapidly changes. This makes rice fields have become unique ecosystem (Edirisinghe and Bambaradeniya, 2006).

1.2.5 Growth stages of rice

The life cycle of rice plants varies from 105 to 145 days from germination to maturity which depend on the rice variety and the surrounded environment (Moldenhauer *et al*., 2012). The farmers must be able to know and comprehend the growth stages of rice because they have to manage some practices appropriately, along a rice growing season (e.g. transplanting, irrigation, fertilization, weeding, harvesting).

Rice growth can be divided into three main stages of development (Peace Corps, 1980; International Rice Research Institute, 2007) (Figure 3).

I. The vegetative stage is characterized by active tillering, a gentle increasing in plant height and continuous emerging of leaf at rice plant intervals. This stage can be divided into three substages.

a) Seedling substage: starts with the emergence of the radicle and lasts until the dawning of tillering. The seedling period usually ranges from 15 to 30 days depending on seed preparation, nursing techniques, fertilizer, and climatic conditions.

b) Transplanting substage: transplant the rice seedlings into puddled fields. This stage can be shorten significantly depending on the handling of the seedlings.

c) Tillering substage: begins with the appearance of the first tiller or shoot from the auxiliary bud on the lowest internode. This stage continues up to the maximum tillering.

II. The reproductive stage is characterized by culm elongation, decreasing in tiller number, booting, appearing of the flag leaf, heading and flowering. This stage lasts approximately 30 days and can be separated into three substages:

a) Booting substage: the panicle can be seen with the naked eyes. This substage lasts approximately 15-20 days in all rice varieties. The internodes rapidly grow, causing the culm to shoot up to the top of rice plant bearing the developing panicle.

b) The Heading substage: the emergence of the panicle from the protective flag leaf sheath. This substage generally lasts until 90% of the panicles have emerged from their sheaths.

c) The Flowering substage (Anthesis): begins with the appearance of the first anthers from the uppermost spikelet on each panicle. During flowering, wind and insect are the main pollinators to transport pollen from the anthers to stigma.

III. The ripening stage: starts with the fertilization and continues through grain ripening, approximately 25-35 days regardless of variety and that can be devided into three substages:

a) The Milk substage: the endosperm begins to form as a milky liquid. This stage, rice is very easy to attack by sucking insect pests.

b) The Dough substage: the milky liquid begins to be a solid into a white grain.

c) The Maturity substage: the grain is ripe, or matur (the endosperm becomes hard and opaque). The leaves of the rice plant begin to turn yellow when the grains ripen. The maturity stage is completed after more than 90% of the grains in the panicles have ripened. Mature grains usually encounter a chang in color and turn to a golden brown.

The varied practices conducted in rice fields during a short term period, have made high diversity of organism. Because rice field is a temporary ecosystem, so it can be used as food source, shelter, breeding and nesting site, and also offer temporary refuge for some groups of animal which visit this area for a variety of purpose.

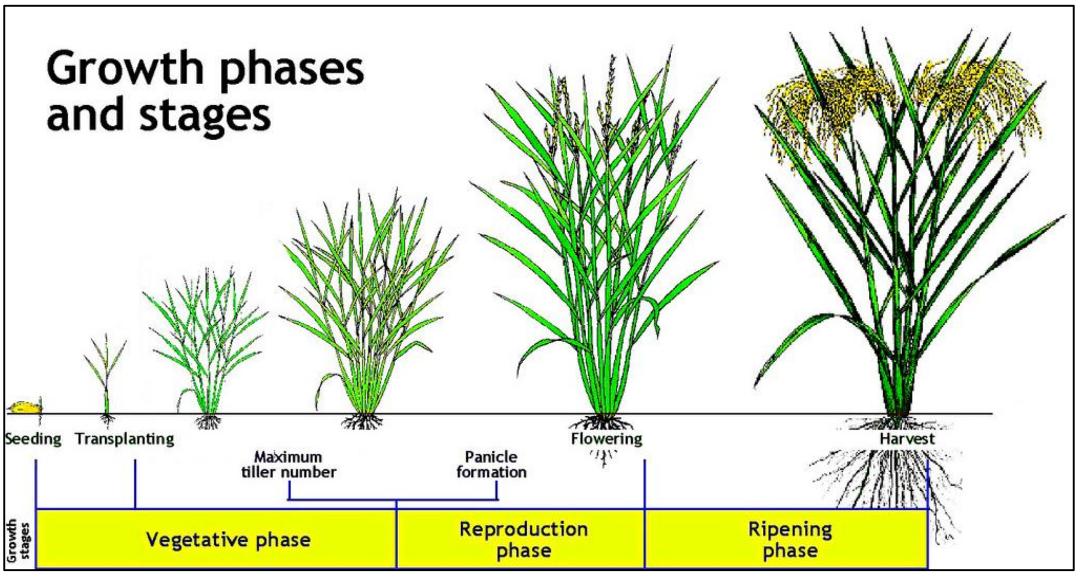

Figure 3 Three stages of rice plant in a rice growing season (International Rice Research Institute, 2007)

1.2.6 Rice insect pests

Rice plants are attacked from more than 100 insect pest species and about 20 species of pest can cause in an economic damage (Pathak and Khan, 1994). These insect pests attack the rice plants from the seedling to maturity and can feed on all parts of the rice plant. The insects that harm rice can be classified into five main groups according to the type of damage they cause (Sherif *et al*. 2005)

1. Root feeders are insects that partially or totally develop in the soil. For example, termites (Oder Isoptera) that are pests in upland rice fields and the rice water weevil; the larvae of thid insect group severely reduce the root system, reflecting low rice yield.

2. Stem borers (Oder Lepidoptera) larvae live in rice stems, resulting in two symptoms of damage. During vegetative stage, the larvae kill the central shoots resulting in "dead heart" and thus the tillering is reduced. During reproductive stage, the larvae feed inside the shoots directly under the panicle which becomes empty with no filled grains, and appear as white panicles called "white heads". The latter symptom is more responsible for yield losses than the former one, because rice plants can not compensate for white heads.

3. Rice hoppers (Order Homoptera) are leafhoppers (Family Cicadellidae) that attack all aerial parts of the rice plant, and planthoppers (Family Delphacidae) which attack the stems. Both groups are piercing-sucking insects, removing the plant sap. The heavily damaged plants exhibit the symptom of "hopper burn". These insects can also transmit virus diseases.

4. Defoliators, e.g. rice leaf miners, *Hydrellia* spp. damage the rice leaves, and thus reduce the photosynthetic capacity of rice plants. However, foliage removal by most of defoliators is usually below the yield reducing level.

5. The stink bugs (Order Hemiptera) penetrate the developing grain with their sucking mouth parts and feed on fluids of the spikelet during milky stage resulting in "pecky rice". The latter symptom reduces the values of rice grain in marketing.

1.2.7 Cultural practices in rice field

Cultural practices are caused by the actions of human that are more harmful to rice fauna. In rice field, cultural practices such as plowing, mowing, and harvesting by mechine induce a high mortality rate in spider populations which is the main predator inhabiting in the rice ecosystem. (Luczak, 1979; Riechert and Lockley, 1984). However, some entomologists noted that some groups of spiders and insects can move to nearby undisrupted areas before the harvesting (Tsutsui et al. 2016)

Accumulating of chemical use has indicated some problems to spiders. It seems that some treatments induce a decreasing in spider diversity and density as well as increasing in pest population. Samu *et al.* (1992) demonstrated that the webs of orb-web spiders contain large quantities of chemicals agents; the droplets of chemical always remain in the web and when these spiders eat their webs daily before rebuilding new one, they will be accumulated chemicals in their body. This study suggests that web building species are more affected by chemicals treatments.

Few studies have studied the impact of different farming systems with different communities of spiders. Most existing studies have compared three farming systems including organic, integrated and conventional. Resosudarmo (2010) showed that the diversity and density of spiders were higher in the organic farming system than in the conventional one. It must be realized the way to conserve the diversity of spider fauna in rice field or other agricultural area is reducing an application of pesticides and promoting some activities which may build up spider population into the fields (Alderweireldt, 1994).

1.3 Objectives

There are three objectives of this study

1. To examine changes in population density of *Tetragnatha* spider in different stages of rice.
2. To investigate prey composition of *Tetragnatha* spider in each stage of rice.
3. To study the proportion between captured prey of *Tetragnatha* spider and available prey in each stage of rice.

CHAPTER 2

POPULATION DYNAMICS AND PREY COMPOSITION OF TETRAGNATHA SPIDER IN SEMI-ORGANIC RICE FIELD OF RANOT DISTRICT, SONGKHLA PROVINCE, SOUTHERN THAILAND

This work was submitted to the Journal Zoological Studies

Population dynamics and prey composition of *Tetragnatha* spider in semi-organic rice field of Ranot District, Songkhla Province, Southern Thailand

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Abstract. *Tetragnatha* (Latreille 1804) spiders are common predators in rice field ecosystems, which feed on various kinds of insects, but their population dynamics and their prey with the progress of rice growing stages are poorly understood. Therefore, the population dynamics and prey composition of *Tetragnatha* spiders in semi-organic rice fields in southern Thailand during four stages of rice plants, including vegetative growth stage, reproductive stage, ripening stage, and after-harvesting stage, were assessed in this study. The results showed that species richness and abundance of *Tetragnatha* spiders were significantly higher in the reproductive stage of the rice plants than in the other stages. The main prey families captured by *Tetragnatha* spiders were different among stages of rice plants. Chironomidae and Corixidae were the main prey in the vegetative growth and the reproductive stages. Insects with soft body and have high activity in the same period with building web of *Tetragnatha* spider tended to be caught in the web easily. It is concluded that the stage of rice plants, which provided different food and web-attached structure of habitat for spiders in the rice ecosystems influenced to both the spider populations and prey compositions.

Keywords: Long-jawed spider, Natural enemy, Paddy field, Rice growing season

2.1 Introduction

Predators play an important role in ecosystems by controlling the number of prey and limiting growth rate of prey populations (Nyffeler 2000). In agricultural ecosystems, population dynamics are of special interest because predators have the potential to maintain insect pest populations at a low equilibrium level (Hassell 1978).

Spiders are common generalist predators in agricultural ecosystems, which feed on various kinds of prey, especially on insects. It exhibits a high diversity in agroecosystems, and serve to limit the number of prey populations (Nyffeler 2000; Venturino et al. 2008). Many agricultural entomologists and arachnologists demonstrated the important role of spiders as a major natural control agent, which have a high potential in regulating insect pest populations, especially in rice fields (Sigsgaard 2000; Nyffeler and Sunderland 2003; Sebastian et al. 2005; Ludy 2007; Tahir et al. 2009). For example, researchers reported that spiders were main predators of leaf folders, cut worms and stem borers while it also traps small insect pests, such as thrips, planthoppers, and aphids (Samiyyan and Chandrasekaran 1998; Landis et al. 2000).

Tetragnatha or long-jawed spiders are a dominant group of web-building spiders found in rice fields (Sebastian et al. 2005). They prefer to live in wet habitats, especially during rice growing season in rice ecosystems. Previous studies showed that *Tetragnatha* preys on various rice insect pests. For example, Tahir et al. (2009) found that main prey orders caught in the webs of *Tetragnatha* spiders were Lepidoptera, Diptera, Homoptera, Coleoptera, Hymenoptera and Orthoptera. Webs of *Tetragnatha* spiders trapped and forced mirid bugs onto ground which is the hunting zones of wolf spiders (Takada et al. 2013). Moreover, some studies found that *Tetragnatha* spiders exhibited a prominent spatial and temporal dynamics in rice ecosystems (Butt et al. 2010; Tsutsui et al. 2016).

There are increasing demand for enhancing the sustainability of agriculture by reducing the chemical use and applying the biological control techniques in rice ecosystem. As spider is amongst the best biological control agent, thus better understanding of how population and prey composition of spider change along the rice growing season in tropical rice field is needed. However, most of the previous studies concerning spider populations and their prey were conducted in only a particular stage of rice plants (Wang et al. 2004; Tahir et al. 2009; Tsutsui et al. 2016) and only one covered all the stages of rice plants (Butt et al. 2010). Here, we examined the population changes of *Tetragnatha* spiders, prey compositions, and prey availability for the spiders in all stages of rice plants along the rice growing season in insecticide-free rice field. As prey community could change along rice planting period, it was hypothesized that population dynamics and prey utilization patterns of *Tetragnatha* spiders are closely associated with the progress of rice growing stages. The result from this study can be useful for applying *Tetragnatha* spider as a biological control agent in rice field in the future.

2.2 METHODS

2.2.1 Study site

This study was conducted in rice fields located in Bankhao, Ranot District, Songkhla Province, southern Thailand (7° 50' N, 100° 13' E). In this area, three semi-organic rice fields with no chemical insecticides and herbicides were applied but chemical fertilizer was used. Each rice field covered around 5 ha and was the same stage of rice planting (start farming in similar time) between the field. All fields were under supervision of the Agricultural Extension Office of Ranot District, Songkhla Province for the purpose of producing rice in good quality and safety. The landscape structures surrounding rice fields were generally similar among three sites, namely, other semi-organic rice fields, ditches, small track and small patches of oil palm plantation (figure 4). The cultivated rice variety was Pathumthani fragrant rice, which is the most common rice variety in this area.

Figure 4 Three study sites in Ranot District, Songkhla Province

2.2.2 Vegetation measurement

Vegetation complexity of rice plant was estimated by a 1.5 m pole. The method consists of placing the pole in a perpendicular position from the ground and record the plant height and plant contacted to the pole (Corcuera et al. 2008; McNett and Rypstra, 2000). The height of rice plants continuously increases from the vegetative growth stage to reproductive stage, and thereafter stays rather steady until the rice is harvested. The rice complexity was different between stage; increasing from the vegetative stage, the reproductive stage and the ripening stage, respectively (Table 1).

Table 1 Description of rice growth in each stage of Pathumthani fragrant rice variety

	Vegetative	Reproductive	Ripening	After-harvesting
Days after planting	40-50	70-80	100-110	After 120
Height (cm)	40-50	90-100	80-90	10-20 (straw)
Vegetation complexity	3.0 (low)	5.5 (moderate)	7.9 (high)	-
Important characteristics	Active tillering	Culm elongation, emergence of the flag leaf, heading and flowering.	Grain increases in size and weight, changes from green to gold color at maturity.	Rice stubble

*Vegetation complexity showed the mean number of rice plant contacted to the pole.

2.2.3 Field observation

In this study, field samplings were carried out during a rice growing season from November 2015 to March 2016. The sampling in the four stages of rice, including vegetative growth stage, reproductive stage, ripening stage and after-harvesting stage were conducted, respectively. All sampling was conducted at night between 1900h to 2200h because feeding activity of *Tetragnatha* spiders is highest (Kiritani et al. 1972; V. Saksongmuang, personal observation). During rice growing season, the temperature ranged from 24-26 °C and the relative humidity was relatively high which was 80-100%.

2.2.4 Spider collection

Tetragnatha spiders were collected in 15 sampling points laid systematically in each stage of one rice field. Both visual searching and sweep netting method were applied in each sampling point. For visual searching, spiders were captured by hand in a 1x1m quadrat. For net sweeping, a 35 cm diameter insect net with a 1 m handle was swept for 5 sweeps per sampling points (1 meter from the paddy edge). Both methods were applied systematically in the same sampling point but not exactly at the same spot. Spider sampling was conducted for three days per rice field in each stage of rice planting. The captured *Tetragnatha* spiders were preserved in 75% alcohol. We identified adult spiders to species based on Riceland Spiders of South and Southeast Asia (Barrion et al. 1995).

2.2.5 Captured prey and prey availability

Captured prey which defined as all arthropod found in spider webs, was investigated by direct searching from webs of *Tetragnatha* spiders along a 50m line transect within 50 minutes in each rice field, each night. Three nights were conducted in each stage per rice field. The time, when the one was manipulated with a web and a spider, would not be included in the 50 min of direct searching. All prey items (dead, alive, partly eaten, chewed up, or even still in the possession of the web resident) as well as *Tetragnatha* spiders were picked up using forceps, and preserved in 75% alcohol. Prey availability was estimated by sweep netting. Fifteen sweeping points were set in each rice field, in which five sweeps per sweeping point were conducted in the same time with spider collection. Available prey in the upper strata of rice plants was collected by this sampling technique. The prey captured by spiders and available prey were investigated at the same period and in the same rice fields as spider were collected, however, different sampling points were used for sampling *Tetragnatha* spiders, captured prey and available prey. Both captured and available prey were identified to family level using Rice-Feeding Insects of Tropical Asia (Shepard et al. 1995) and Arthropod Biodiversity, Taxonomy and Identification (International Rice Research Institute 2010).

2.2.6 Statistical analysis

The effect of rice stages (vegetative growth stage, reproductive stage, ripening stage and after-harvesting stage) on the total spider abundance and the abundance of each *Tetragnatha* species by both sampling methods (i.e. visual searching and net sweeping) were analyzed using a generalized linear model (GLM) with a Poisson error distribution, because the dependent variables are count data. The fixed factor in the model was the rice stages, and the random factor was the identity of rice fields. All statistical analyses were conducted with R-3.2.2 (R Development Core Team 2016).

Prey selectivity of the spider webs was determined using Ivlev's electivity index (Ivlev 1961) based on prey availability and captured prey compositions (Alderweireldt 1994; Diehl et al. 2013). These indices were calculated only for dominant prey families that were present at all rice stages. The Ivlev index (IE) was estimated by the following formula:

$$\mathrm{IE} = \frac{r - p}{r + p}$$

Where r is the percentage contribution of individuals from a prey family to the captured prey composition and p is the percentage contribution of the same prey family to the available prey composition. The Ivlev index ranges from +1 (prey family overrepresented in webs) to -1 (prey family underrepresented in webs), where 0 indicates random feeding (prey family appears with the same percentage in captured prey and available prey).

2.3 RESULTS

A total of 192 spiders of *Tetragnatha* were captured in three semi-organic rice fields over the four stages of rice plants. Among them, 83 adults and 27 juveniles were captured based on visual searching, and 54 adults and 28 juveniles were captured by sweep netting. Only adult spiders were identified to the species level. We found six species of *Tetragnatha* spider, including *Tetragnatha javana* (Thorell, 1890), *Tetragnatha mandibulata* (Walckenaer, 1841), *Tetragnatha maxillosa* (Thorell, 1895), *Tetragnatha nitens* (Audouin, 1826), *Tetragnatha vermiformis* (Emerton, 1884) and *Tetragnatha virescens* (Okuma, 1979). Two species, *T. javana* and *T. maxillosa* were the most abundant, representing 40.1% and 29.9% of the total adults while *T. nitens*, *T. mandibulata*, *T. virescens and T. vermiformis* was 11.6%, 9.5%, 8.0 and 1.4%, respectively.

2.3.1 Effect of rice stage on *Tetragnatha* spider

The stage of rice plants significantly affected the abundance of *Tetragnatha* spiders in semi-organic rice fields, which was demonstrated by visual searching method (GLM, $X^2 = 44.66$, df = 3, $p < 0.001$) as well as sweeping method (GLM, $X^2 = 35.72$, df = 3, $p < 0.001$). From both sampling technique, the abundance of *Tetragnatha* spiders was significantly higher in reproductive stage than in the other stages ($p < 0.05$) and but was not significantly different between vegetative growth, ripening stage and after-harvesting stage ($p > 0.05$) (Figure 5).

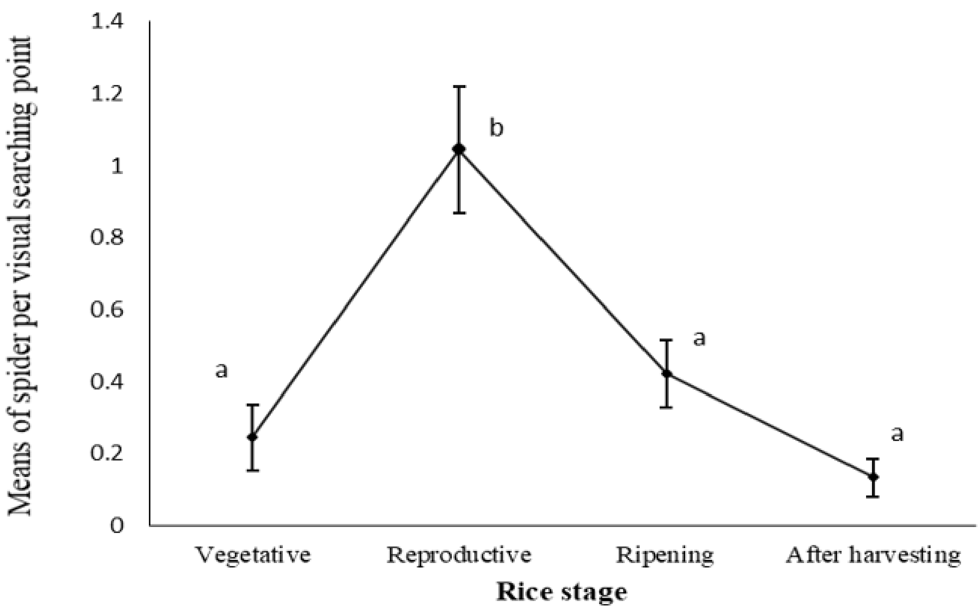

Figure 5 Mean number of *Tetragnatha* spider (± S.E.) in each stage of rice by visual searching method. The different letter means the significantly difference of mean number between rice stage (Tukey's test, $P < 0.05$).

The rice stage generally affected the number of species and also the abundance of each *Tetragnatha* species. Species richness and abundance were varied in different stages of rice plants. The highest species of *Tetragnatha* spider (6 species) were found in reproductive stage while the lowest (2 species) were found in after-harvesting stage. In vegetative growth stage, the abundance of *Tetragnatha* spider did not differ between species. In reproductive, *T. javana* and *T. maxillosa* were significantly higher than other species. In ripening stage, *T. javana* and *T. maxillosa* were obviously the most abundant. *T. javana* was also a dominant group in the fields in after-harvesting stage. The result showed that the abundances of *T. javana* and *T. maxillosa* fluctuated from stage to stage, while the abundance of *T. mandibulata, T. nitens, T. vermiformis* and *T. virescens* were not significantly different between the stages (Figure 6).

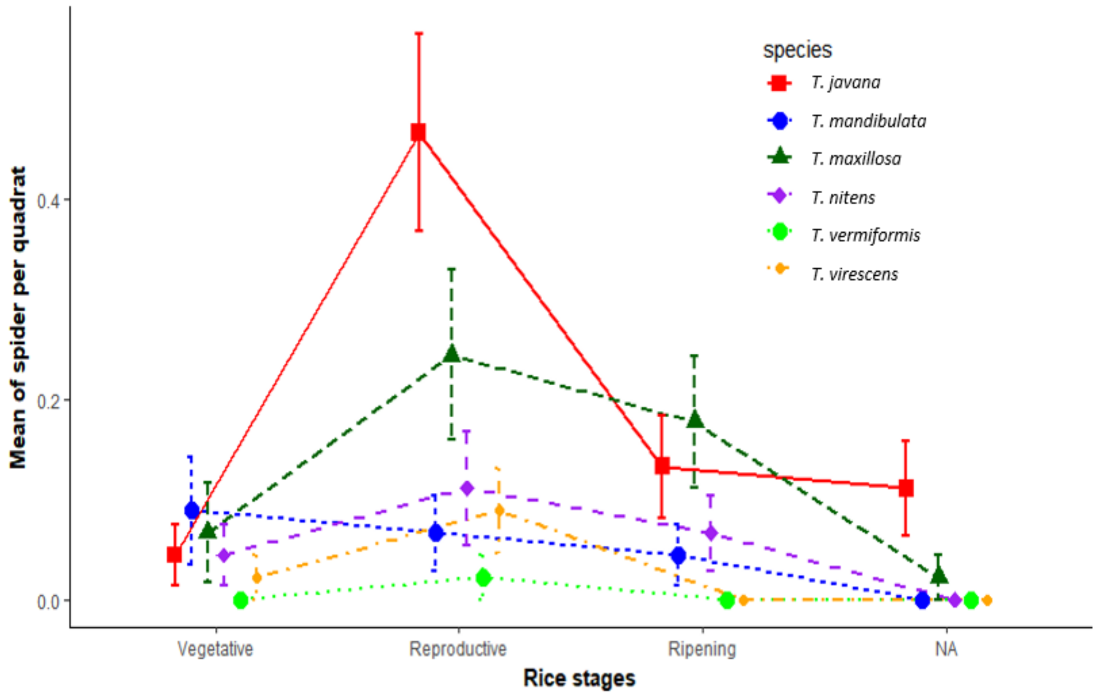

Figure 6 Mean number (± S.E.) of different *Tetragnatha* species in each stage of rice

2.3.2 Prey availability

Prey availability estimated by sweep netting showed that the number of insects rapidly increased from the vegetative growth stage to be highest in the reproductive stage. After that, it gradually decreased in ripening and after-harvesting stage, respectively. Dominant families of available prey were different among rice stages. In both vegetative growth and reproductive stages, the most dominant family was Chironomidae, while Cicadellidae was the second in reproductive stage. In ripening stage, number of chironomids decreased, while Cicadellidae increased and became the dominant insects. In after-harvesting stage, Chironomidae and Acrididae were most frequently trapped in sweep netting (Table2).

Table 2 Prey availability estimated by net sweeping in each rice stage (A = Vegetative growth stage, B = Reproductive stage, C = Ripening stage, D = After-harvesting stage)

Main family of available prey		**Number of individual (Mean ± S.E.)**			
		A	**B**	**C**	**D**
Diptera	Chironomidae	132.7±17.3	109.0 ±7.8	6.0 ±1.0	47.7±8.5
	Cecidomyiidae	-	2.3 ±0.7	0.3 ±0.3	5.3 ±1.5
	Tipulidae	-	15.3 ±2.2	6.7±2.2	3.0 ±2.1
Hemiptera	Cicadellidae	8.0 ±3.0	59.3 ±10.8	103.7±9.8	9.7±2.7
	Delphacidae	1.3 ±0.7	3.0 ±2.5	2.7±0.9	2.7±1.5
	Corixidae	4.3±1.5	5.0 ±2.1	2.3±1.2	1.0 ±0.6
	Miridae	3.0 ±0.6	14.7±4.8	3.3 ±1.2	3.0 ±0.9
Orhtoptera	Tettigoniidae	9.7 ±2.2	4.0 ±1.2	12.0 ±2.1	9.0 ±3.0
	Acrididae	4.3 ±1.5	0.7±0.7	7.0 ±1.7	16.0 ±2.3
Odonata	Coenagrionidae	4.3 ±1.2	5.0 ±2.0	3.3 ±1.9	-
Coleoptera	Coccinellidae	7.7±1.8	12.3 ±2.0	7.7±2.4	4.0 ±1.7
Lepidoptera	Pyralidae	2.3 ±1.3	16.3±2.6	3.7±0.3	-
Ephemeroptera	Baetidae	0.3 ±0.3	4.0 ±0.6	1.7±0.9	-
Aranea	Spiders	33.0±5.5	91.3 ±7.7	101.7±8.4	49.3 ±2.7
Others	Other families	50.7±6.6	125.0 ±14.4	66.7±7.3	66.0±9.6
Total number		279.0±12.7	469.7±35.4	348.0±30.6	217.7±20.7

2.3.3 Captured prey

A total of 928 prey items were collected from *Tetragnatha* spider webs across all stages of rice plants, which Chironomidae and Corixidae being dominant. However, the major prey varied in different stage of rice. In vegetative growth stage, main prey families were Chironomidae and Corixidae. In reproductive stage, a higher number of prey was found in the family Corixidae, Chironomidae and Baetidae. In ripening stage, Delphacidae and Chironomidae were the main prey of *Tetragnatha* spider. There was no obvious dominant prey in after-harvesting stage (Table 3).

Table 3 Number of main insect prey captured by spider webs in each rice stage (A = Vegetative growth stage, B = Reproductive stage, C = Ripening stage, D = After-harvesting stage)

Main family of captured prey		**Number of individual (Mean ± S.E.)**			
		A	**B**	**C**	**D**
Diptera	Chironomidae	5.1±0.9	19.2 ±1.8	0.4 ±0.2	0.2 ±0.1
	Cecidomyiidae	0.2±0.1	0.7±0.2	0.2 ±0.1	0.1 ±0.1
	Tipulidae	-	1.2 ±0.4	0.1 ±0.1	-
Hemiptera	Corixidae	2.6±0.4	33.3 ±7.0	-	-
	Delphacidae	-	0.8±0.3	0.7±0.2	0.1±0.1
	Notonectidae	-	1.2 ±0.6	-	-
Odonata	Coenagrionidae	0.2 ±0.1	0.7±0.3	-	-
Ephemeroptera	Baetidae	-	2.7±0.3	-	0.2 ±0.2
Others	Other insects and Chelicerata	1.0 ±0.4	5.9±1.1	1.7±0.6	0.1±0.1
Unidentified	Scrap	1.7±0.5	15.7±1.8	6.8±1.0	0.3 ±0.2

From the proportions of captured prey and available prey in each stage of rice, Corixidae was clearly overrepresented in *Tetragnatha* webs in vegetative growth and reproductive stage (Ivlev index = 0.85 and 0.95, respectively). In ripening stage, Cecidomyiidae, Delphacidae and Chironomidae were obviously overrepresented (Ivlev index = 0.99, 0.97 and 0.81, respectively). Baetidae and Cecidomyiidae were distinctly overrepresented in after-harvesting stage (Ivlev index = 1 and 0.83, respectively). In general, Acrididae, Cicadellidae, Entomobryidae and Pyralidae were underrepresented in spider webs in almost stages of rice (Ivlev index < 0), even they had higher abundance in prey availability (Figure 7).

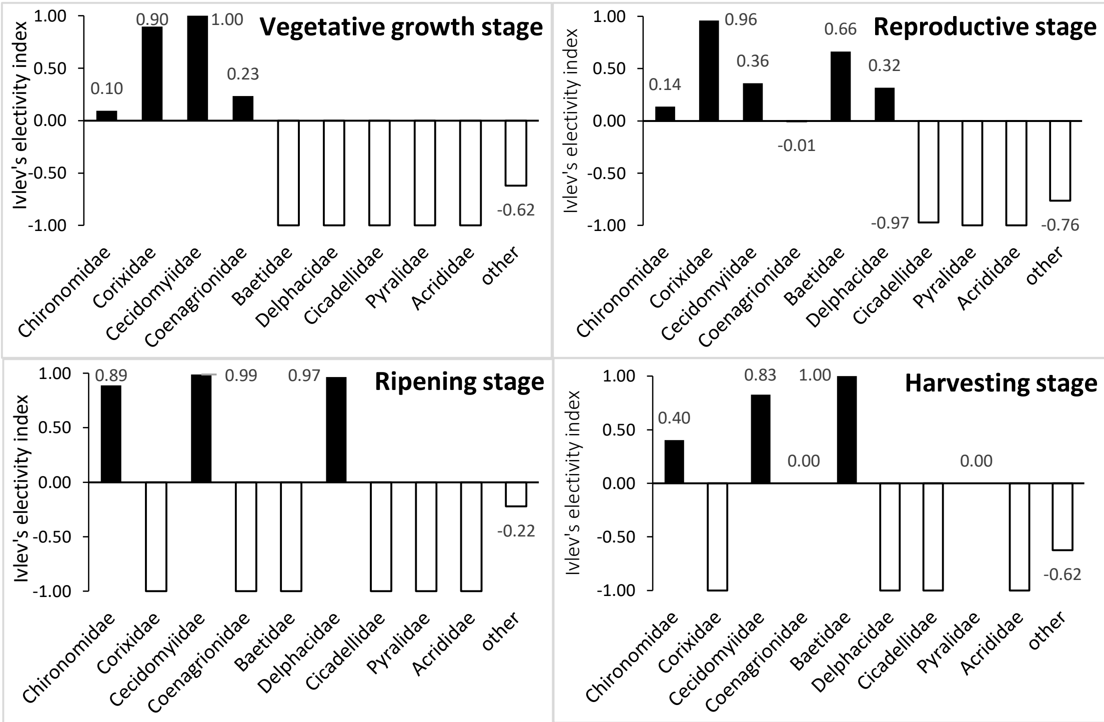

Figure 7 The Ivlev's electivity indexof main prey family in each stage of rice plants

2.4 DISCUSSION

2.4.1 Population dynamics of *Tetragnatha* spiders

Our study showed that both abundance and species richness of *Tetragnatha* spiders was highest in reproductive stage of rice plants, while they were lowest in after-harvesting stage. The highest spider abundance and species richness in reproductive rice stage could be resulted from the following two reasons. First, prey availability and prey diversity for spiders was the highest in this stage from the presence of rice flower and water habitat. It is known that rice flowers which occur in this stage can be used as a food sources for a wide range of insects (Wilson et al. 2014) while rice field is still flooded, provide habitat for many species of aquatic insects such as midge flies, water bugs (Zhi-yu et al. 2011). Therefore, many insects moved in and used resources in the rice field in reproductive rice stage (Wilson et al. 2014). Previous studies reported that the density and the growth rate of *Tetragantha* spider had a significant positive correlation with the abundance of dipterans in rice fields (Takada et al. 2014; Tsutsui et al. 2016). According to our results, the number of *Tetragnatha* spiders was increased when the number of dipterous insects, especially midge flies and crane flies, increased in the early growing season. Second, rice reproductive stage offers an optimum rice stem complexity to support spider webs, as rice plants does not appear to be too sparse (in vegetative stage) nor too dense (in ripening stage) in this stage, therefore spiders can effectively attach their webs in an appropriate size and move easily to catch their prey (Jayakumar et al. 2010). According to many previous studies, found that the availability of attachment substrate for webs of web-building spider was determined by vegetation complexity because the increasing complexity of the habitat offers more shelter, food, and microhabitats for the spiders (McNett and Rypstra 2000; Sudhikumar et al. 2005; Öberg and Ekbom 2006). On the other hand, both spider populations and species richness were low in after-harvesting stage. At this stage, only rice straw and a little amount of vegetation remained in the rice fields, thus the population of insect prey and microhabitats for supporting spider webs were reduced. When habitat is not suitable, spider in rice field normally move to other habitat which provide more suitable condition such as levees or ditches (Bambaradeniya and Edirisinghe 2008; Miyashita et al. 2014; Tsutsui et al. 2016). Therefore, our finding supports the hypothesis that population dynamics of *Tetragnatha* spiders change with the progress of rice stages because of the temporal change in insect prey availability and availability of attachment substrate.

Our study showed that *T. javana* is the most dominant species in rice fields, which was similar to the studies in India (Jayakumar et al. 2010) and Pakistan (Tahir 2008), but was different from those in Japan and China. In Japanese rice field, a dominant species is *T. caudicula* (Tsutsui et al. 2016), while *T. nitens* is a dominant species in China (Barrion et al. 2012). The dissimilarity in dominant species may due to the species distribution along geographical regions.

2.4.2 Prey compositions

In this study, the captured prey of *Tetragnatha* spiders were different between different stages of rice plants. Midge flies, mayflies and water bugs were main prey for spider in vegetative growth stage and reproductive stage. This may be because high water levels in rice fields support the abundance of these detritus-feeding and plankton-feeding insects. This is consistent with Ishijima et al. (2006) who found that dipterous insects including chironomids (midge flies) were an important alternative prey for spiders in the early cropping season. In ripening stage, the main captured prey was changed to Delphacidae which is the common rice insect pests in southern, Thailand. The important finding of our study is that *Tetragnatha* spiders change their diets from detritus-feeding insect to herbivorous insect along rice growing stage. It corresponds to the previous studies which suggests that non-pest insects such as dipterous insect may sustain spider population and thereafter could strengthen top-down effect of spider on insect pests (Settle et al. 1996; Bardwell and Averill 1997; Ishijima et al. 2006; Motobayashi et al. 2006).

Main captured prey of *Tetragnatha* spiders in this study were similar to some previous studies of Rapp (1978) and Yoshida (1987) which found that *Tetragnatha* spiders mainly feed on midge flies, mayflies, mosquitos and other nematocerous dipterans of small body size. A number of previous studies demonstrated that insects with small size, poor flying ability, many appendages and a high abundance in the same height with spider webs were caught in spider web easily (such as Chironomidae, Cecidomyidae, Tipulidae, some Hemiptera and small Ephemeroptera) (Craig 1986; Ludy 2007; Tahir 2009). For the water bug in the family Corixidae, the reason for its high abundance in spider webs is unclear. It is possible that these water bugs were trapped during their migratory flight from rice field to another place nearby when water in rice field was drained out in the late of reproductive stage (around 70 DAP). Dispersal of water bugs is driven by a number of physical, environmental, ecological and physiological factors (Savage 1989), including decreasing of water level, deterioration in habitats, excessing of predators, high density of aquatic insects (Young 1966; Pajunen et al. 1969; Boda 2003). Boda and Csabai (2009) revealed that peak dispersal flight of Corixidae began at 1900 h, and reached its maximum at 2100 h, which corresponds to the highest feeding activity period of *Tetragnatha* spiders (Kiritani et al. 1972). Our result is slightly in contrast to Butt et al. (2010) who studied on diet composition of *T. javana* in rice ecosystem of Pakistan (observation time period were 0630-0730 h and 1700-1800 h) and found that main prey of *T. javana* were Lepidoptera, Diptera and Hemiptera. We found that Pyralidae (Lepidoptera) had a low incidence in every stage of rice plants and Cicadellidae (Hemiptera) had a high abundance in reproductive and ripening stage of rice plants, but it was proportionally low in

Tetragnatha webs. This difference may be due to the difference in observation times in a day. It is interesting to study the diet composition of *Tetragnatha* in rice field over their entire feeding period in a day (1800-0800h) in the near future, which could lead to a more precise evaluation for the role of spiders in rice fields.

From electivity index, prey compositions in *Tetragnatha* webs did not simply represent insect availability in rice fields. Some groups of insects were caught disproportionately higher in webs than in availability based on sweep netting, including Corixidae, Cecidomyidae, Delphacidae and Baetidae. The overrepresentations in webs of Corixidae in vegetative growth stage and reproductive stage might be due to sampling technique (sweeping method) which could not cover water insects. On the other hand, some main groups of available prey, including Acrididae (Orthoptera), Cicadellidae, Miridae (Hemiptera), and Pyralidae (Lepidoptera), were captured in *Tetragnatha* webs less than their availability in the rice fields. The underrepresentation of these groups in spider webs may be due to their ability to avoid spider webs (Nentwig 1980). Three reasons for this underrepresentation in spider webs are considered here. First, the morphology or physiology of these insect groups can make them avoid or escape from spider webs, such as large body size, strong mandible, good flying ability, streamline shape (Turnbull 1973; Nentwig 1987). For example, insects in the order Orthoptera having a large body size and strong mandible can escape quickly when they are trapped in webs. Second, it is due to the low capture capability of *Tetragnatha* threads which is less adhesiveness (Yoshida 1987). In addition, insects such as butterflies or moths have numerous scales, making adhesiveness of spider webs inefficient. For example, itis possible that some insects group such as mirid bugs and leafhoppers were trapped by horizontal web of *Tetragnatha* spider and after that fall to the ground because of the inefficient web. Third, these insect groups may use different rice plant parts for habitat or feeding in comparison to the parts where spiders build their webs. For example, collembolan, live on ground, has less possibility to be trapped in spider webs even they are the dominant group of scavenger in rice fields (Bambaradeniya and Edirisinghe 2008).

This study found that the main group of prey of *Tetragnatha* spider were detritus feeders, plankton feeders and insect pests which trapped in web more than other predators or parasitoid. This finding might be useful for applying *Tetragnatha* spider to be used as a good biological control agent in rice field because *Tetragnatha* spider do not decrease the role of other predators and parasitoid in rice ecosystem. Moreover, understanding of the change in density and prey composition along the rice growing season of *Tetragnatha* spider which is the main natural enemy in rice ecosystem, can be an important tool in managing rice ecosystem in natural control strategy.

2.5 CONCLUSIONS

In this present study showed that the population of *Tetragnatha* spider was changed along the rice growing season with correspond to the changing in insect prey availability and sites for web attachment. Prey composition of this spider was also changed in the different stage of rice plant because different group of insect used different resource in each stage of rice.

2.6 ACKNOWLEDGMENTS

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2.7 LITERATURE CITED

Alderweireldt M. 1994. Prey selection and prey capture strategies of linyphiid spiders. Bull Br Arachnol Soc 9:300-308.

Bambaradeniya CN, Edirisinghe JP. 2008. Composition, structure and dynamics of arthropod communities in rice agroecosystem. J Sci Biol 37(1):23-48.

Bardwell CJ, Averill L. 1997. Spiders and their prey in assachusetts cranberry bogs. J Arachnol 25:31-41.

Barrion AT, Litsinger JA. 1995. Riceland Spiders of South and Southeast Asia.CAB International, Wallingford, UK.

Barrion AT, Villareal SS, Catindig JLA, Cai D, Yuan QH, Heong KL. 2012. The spider fauna in the rice agricultural landscape of Hainan Island, China: Composition, abundance and feeding structure. Asia Life Sci 21(2):625-651.

Boda P, Csabai Z, Gido Z, Mora A, Devai G. 2003.Migration activity patterns of aquatic beetles and aquatic bugs (Coleoptera, Heteroptera) II – Seasonal flight dynamics of *Helophorus brevipalpis* and *Sigara lateralis*. J Hung Hydrol Soc 83:20-21.

Boda P, Csabai Z. 2009.Seasonal and diel dispersal activity characteristics of *Sigara lateralis* (Leach, 1817) (Heteroptera: Corixidae) with special emphasis on possible environmental factors and breeding state. Aquat Insect 31:301-314.

Butt A, Tahir HM. 2010.Resource Partitioning among Five Agrobiont Spiders of a Rice Ecosystem. Zool Stud 49(4): 470-480.

Craig CL. 1986. Orb-web visibility: the influence of insect flight behavior and visual physiology on the evolution of web designs within the Araneoidea. Anim Behav 34:54-68.

Diehl E, Mader VL, Wolters V, Birkhofer K. 2013. Management intensity and vegetation complexity affect web-building spiders and their prey. Oecologia 173:579-589.

E1978. The Dynamics of Arthropod Predator–Prey Systems, Princeton Univ. Press, Princeton, New Jersey.

International Rice Research Institute. 2010. Arthropod Biodiversity, Taxonomy and Identification. Los Banos, Laguna, Philippines.

Ishijima C, Taguchi A, Takagi M, Motobayashi T, Nakai M, Kunimi Y. 2006. Observational evidence that the diet of wolf spiders (Araneae: Lycosidae) in paddies temporarily depends on dipterous insects. Appl Entomol Zool 41(2):195-200.

Ivlev, V. 1961. Experimental ecology of the feeding of fishes. Yale University Press, New Haven.

Jayakumar S, Sankari A. 2010. Spider population and their predatory efficiency in different rice establishment techniques in Aduthurai, Tamil Nadu. J Biopest 3:20-27.

Kiritani KS, Kawahara S, Sasaba T, Nakasuji F. 1972. Quantitative evaluation of predation by spiders on the green rice leafhopper, *Nephotettix cincticeps* Uhler, by a sight-count method. Res Popul Ecol 13:187-200.

Landis DA, Wratten SD, Gurr GM. 2000. Habitat management to conserve natural enemies of arthropod pests in agriculture. Annu Rev Entomol 45:175-201.

Langellotto GA, Denno RF. 2004 Responses of invertebrate natural enemies to complex-structured habitats: a meta-analytical synthesis. Oecologia 139:1–10.

Ludy C. 2007. Prey selection of orb-web spiders (Araneidae) on fieldmargins. Agric Ecosyst Environ 119:368-372.

McNett BJ, Rypstra AL. 1997. Effects of prey supplementation on survival and web site tenacity of *Argiope trifasciata* (Araneae, Araneidae): a field experiment. J Arachnol 25:352-360.

McNett BJ, Rypstra AL. 2000. Habitat selection in a large orb- weaving spider: vegetation complexity determines site selection and distribution. Ecol Entomol 25:423-432.

Miyashita T, Yamanaka M, Tsutsui HM. 2014. Distribution and abundance of organisms in paddy-dominated landscapes with implication for wildlife-friendly farming. Pp. 45-65. *In* Miyashita T, Nishikawa U (eds) Social-ecological restoration in paddy-dominated landscapes. Springer, Japan.

Motobayashi T, Ishijima C, Takaji M, Murakami M, Tacguchi A, Hidaka K et al. 2006. Effects of tillage practices on spider assemblage in rice paddy fields. Appl Entomol Zool 41(2):371-381.

Nentwig W. 1980. The selective prey of Linyphiid-like spiders and of their space webs. Oecologia 45:236-243.

Nentwig W. 1985. Prey analysis of four species of tropical orb-weaving spiders (Araneae: Araneidae) and a comparison with aranids of the temperate zone. Oecologia 6:580-594.

Nentwig W. 1987. The ecophysiology of spiders. Springer, Berlin.

Nyffeler M. 2000. Ecological impact of spider predation: A critical assessment of Bristowe's and Turnbull's estimates. Bull Br Arachnol Soc 11(9):367-373.

Nyffeler M, Sunderland KD. 2003. Composition, abundance and pest control potential of spider communities in agroecosystems: a comparison of European and US studies. Agric Ecosyst Environ 95:579-612.

Öberg S, Ekbom B. 2006. Recolonisation and distribution of spiders and carabids in cereal fields after spring sowing. Ann Appl Biol 149: 203-211.

Pajunen VI, Jansson A. 1969. Dispersal of the rock pool corixids *Arctocorisa carinata* (Sahlb.) and *Callicorixa producta* (Reut.) (Heteroptera, Corixidae). Ann Zool Fennici 6:391-427.

Rapp WF. 1978. Preliminary studies of *Tetragnatha* (Araneida) as predators of mosquitoes. Mosquito News 38:506-507.

Rypstra AL, Carter PE, R. A. Balfour and S. D. Marshall. 1999. Architectural features of agricultural habitats and their impact on the spider inhabitants. J Arachnol 27:371–377.

Samiyyan K, Chandrasekaran B. 1998. Prey potential and preference of three Rice Dwelling spiders. Madras Agric J 85(7-9):429-438.

Savage AA. 1989.Adults of the British Aquatic Hemiptera Heteroptera: Key with ecological notes. Freshwater Biological Association Scientific Publication No. 50, Ambleside: Freshwater Biological Association.

Sebastian AP, Mathew JM, Pathummal BS, Joseph J, Biju RC. 2005.The spider fauna of the irrigated rice ecosystem in the central Kerala, India. J Arachnol 33:247-255.

Settle WH, Ariawan H, Astuti ET, Cahyana W, Hakim AL, Hindayana D et al. 1996. Managing tropical rice pests through conservation of generalist natural enemies and alternative prey. Ecology 77:1975-1988.

Shepard BM, Banion AT, Litsinger JA. 1995. Rice-Feeding insects of Tropical Asia. International Rice Research Institute, Manila, Philippines.

Sigsgaard L. 2000.Early season natural biological control of insect pests in rice by spiders - and some factors in the management of the cropping system that may affect this control. Eur Arachnol 2000:57-64.

Sudhikumar AV, Mathew MJ, Sunish E, Sebastian PA. 2005. Seasonal variation in spider abundance in Kuttanad rice agroecosystem, Kerala, India (Araneae). Acta Zool Bulg 1:181-190.

Sunderland K, Samu F. 2000. Effects of agricultural diversification on the abundance, distribution, and pest control potential of spiders: a review. Entomol Exp Appl 95:1-13.

Tahir HM, Butt A. 2008. Activities of spiders in rice fields of central Punjab, Pakistan. Acta Zool 54(4):701-711.

Tahir HM, Butt A. 2009. Predatory potential of three hunting spiders inhabiting the rice ecosystems. J Pest Sci 82:217-225.

Tahir HM, Butt A, Sherawat SM. 2009. Foraging strategies and diet composition of two orb web spiders in rice ecosystems. J Arachnol 37:357-362.

Takada MB, Kobayashi T, Yoshioka A, Takagi S, Washitani I. 2013. Facilitation of ground-dwelling wolf spider predation on mirid bugs by horizontal webs built by *Tetragnatha* spiders in organic paddy fields. J Arachnol41:31–35.

Takada MB, Takagi S, Iwabuchi S, Mineta T, Washitani I. 2014. Comparison of generalist predators in winter-flooded and conventionally managed rice paddies and identification of their limiting factors. SpringerPlus 3:1-7.

Tsutsui MH, Tanaka K, Baba YG, Miyashita T. 2016.Spatio-temporal dynamics of generalist predators (*Tetragnatha* spider) in environmentally friendly paddy fields. Appl Entomol Zool 51:631-640.

Turnbull AL. 1973.Ecology of the true spiders (Araneomorphae). Annu Rev Entomol 18:305-348.

Uetz GW. 1990. Prey selection in web-building spiders and evolution of prey defenses. Pp. 93-128In: Evans DL, Schmidt OJ (eds) Insect defense. Adaptive mechanisms and strategies of prey and predators. University of New York Press, Albeny.

Venturino E, Isaia M, Bona F, Chatterjee S, Badino G. 2008. Biological controls of intensive agroecosystems: wanderer spiders in the Langa Astigiana. Ecol Complex 5:157-164.

Wang Z, Yuan Z, Song D, Zhu M. 2004. Analysis on the dynamics of spatial distribution pattern of mixed spider population in rice field. Entomol Sin 11:257-265.

Wilson JJ, Ramakrishnan R, Pavaraj M, Sevarkodiyone SP. 2014. A Study on the Age-Wise and Seasonal Distribution of Spider Fauna in the Paddy and Maize Field. (Athikulam, Virudhunagar District, Tamil Nadu, India). World J Zool 9 (1):13-18.

Yoshida M. 1987.Predatory behavior of *Tetragnatha praedonia* (Araneae: Tetragnathidae). Acta Arachnol 35:57-75.

Young EC. 1966.Observations on migration in Corixidae (Hemiptera: Heteroptera) in

Southern England. Entomol Mag 101:217-229.

Zhi-yu L, Hong Y, Feng-xiang L, Qing F, Yang H. 2011. Occurrence and Population Dynamics of Chironomids in Early-Season Rice Fields. Rice Sci 18(2): 136-141.

CHAPTER 3
CONCLUSION

Tetragnatha spiders (long-jawed spider) can change their population and their prey composition with the progress of rice stage. They build up their population when food and habitat are suitable. This study shows that species richness and abundance of *Tetragnatha* spiders are the highest in reproductive stage whereas the lowest in after harvesting. The main prey families of *Tetragnatha* spider are different among rice stages. Chironomidae make up a greatest captured prey in vegetative growth stage, while Corixidae is the most abundant in the web during reproductive stage. In ripening and after harvesting stage, the captured prey is changed to Delphacidae and Chironomidae, respectively. According to the results, this study further suggests that *Tetragnatha* spiders change their diets from detritus-feeding insect to herbivorous insect along rice growing stage. From the results of the present study it can be concluded that *Tetragnatha* spider can be a good natural enemy and can be used as a biological control agent of rice insect pests along with other natural enemies.

Recommendation for further study

For a better understanding and more precise evaluation of the role of *Tetragnatha* spider in rice field, it is interesting to study the diet composition of *Tetragnatha* spider over their entire feeding period (1800-0800 h) in a day in the future.

REFERENCES

Aiken, M and Coyle, F. A. 2000. Habitat distribution, life history and behavior of Tetragnatha spider species in the Great Smoky Moutains National Park. The Journal of Arachnology 28:97–106.

Alderweireldt, M. 1994. Prey selection and prey capture strategies of linyphiid spiders. Bulletin of the British Arachnological Society 9:300-308.

Butt, A. and Tahir, H. M. 2010. Resource Partitioning among Five Agrobiont Spiders of a Rice Ecosystem. Zoological Studies 49: 470-480.

Chacon, P and Eberhard, W. G. 1980. Factors affecting numbers and kinds of prey caught in artificial spider webs, with considerations of how orb webs trap prey. Bulletin of the British Arachnological Society 5:29-38.

Chatterjee, S., Isaia, M. and Venturino, E. 2009. Spiders as biological controllers in the agroecosystem. Journal of Theoretical Biology 258: 352–362.

Dimitrov, D. and Hormiga, G. 2009. Tetragnathidae. http://tolweb.org/Tetragnathinae /134581(accessed August 16, 2017)

Edirisinghe, J. P. and Bambaradeniya, C. N. B. 2006. Rice Fields: An Ecosystem Rich in Biodiversity. Journal of the National Science Foundation of Sri Lanka 34(2): 57-59.

Hassell, M. P. 1978. The Dynamics of Arthropod Predator–Prey Systems, Princeton University Press, Princeton, New Jersey.

Herberstein, M. E. 2011. Spider Behaviour: Flexibility and Versatility, Cambridge University, Cambridge, United Kingdom.

International Rice Research Institute. 2007. Growth stages of the rice plant. http://www.knowledgebank.irri.org/ericeproduction/0.2._Growth_stages_of_the _rice_plant.htm (accessed August 29, 2017)

Kiritani, K.S., Kawahara, S., Sasaba, T. and Nakasuji, F. 1972. Quantitative evaluation of predation by spiders on the green rice leafhopper, *Nephotettix cincticeps* Uhler, by a sight-count method. Researches on Population Ecology 13: 187-200.

Lissner, J. 2011. The Spiders of Europe and Greenland: Family: Tetragnathidae (Long-jawed Orb Weavers). http://www.jorgenlissner.dk/Tetragnathidae.aspx (accessed September 15, 2015)

Luczak, J., 1979. Spiders in agrocenoses. Polish Ecological Studies 5(1):151–200.

Ludy, C. 2007. Prey selection of orb-web spiders (Araneidae) on field margins. Agriculture, Ecosystems & Environment 119:368–372.

Mathirajan, V. G. 2001. Diversity and predatory potential of spiders in Cotton and Rice ecosystem applied with Thiamethoxane. Ph. D., Thesis. TNAU, Coimbatore-3.

Moldenhauer, K., Wilson, C. E., Counce, Jr. P. and Hardke, J. 2012. Chapter 2: Rice Growth and Development. Arkansas Rice Production Handbook. University Little Rock, Arkansas. pp 9-20.

Nieuwenhuys, E. 2008. Stretch spiders or long jawed orb weavers. http://ednieuw.home.xs4all.nl/Spiders/Tetragnatidae/Tetragnathidae.htm (accessed September 15, 2015)

Nyffeler, M. 2000. Ecological impact of spider predation: A critical assessment of Bristowe's and Turnbull's estimates. Bulletin of the British Arachnological Society 11(9):367–373.

Nyffeler, M. and Sunderland, K. D. 2003. Composition, abundance and pest control potential of spider communities in agroecosystems: a comparison of European and US studies. Agriculture, Ecosystems & Environment 95:579-612.

Ovtsharenko, V. and Tanasevitch, A. 2002. Family Tetragnathidae. http://research.amnh.org/iz/blackrock2/families/tetragnathidae.htm#Tetragnatha (accessed August 16, 2017).

Pathak, M. D. and Khan, Z. R. 1994. Insect Pest of Rice. International Rice Research Institute, Manila, Philippines.

Peace Corps. 1980. Chapter 2 - The growth stages of rice. Rice Production. http://www.nzdl.org/cgi-bin/library.cgi (accessed September 11, 2015).

Resosudarmo, B.P., 2010. Impact of the Integrated Pest Management Program on the Indonesian Economy. The Economic Division, Research School of Pacific and Asian Studies 10:1-30.

Riechert, S.E. and Lockley, T. 1984. Spiders as biological control agent. Annual Review of Entomology 29, 299–320.

Samu, F., Matthews, G.A., Lake, D. and Vollrath, F. 1992. Spider webs are efficient collectors of agrochemical spray. Journal of Pest Science 36: 47–51.

Samu, F. and Biro, Z. 1993. Functional response, multiple feeding and wasteful killing in a wolf spider (Araneae: Lycosidae). European Journal of Entomology 90: 471-476.

Sebastian, A. P., Mathew, J. M., Pathummal, B. S., Joseph, J. and Biju, R. C. 2005. The spider fauna of the irrigated rice ecosystem in the central Kerala, India. Journal of Arachnology 33:247-255.

Sherif, M.R., Hendawy, A.S. and El-Habashy, M. M. 2005. Management of rice insect pests. Egypt. Journal of Agricultural Research 83 (5A):111-130.

Sigsgaard, L. 2000. Early season natural biological control of insect pests in rice by spiders - and some factors in the management of the cropping system that may affect this control. Proceedings of the 19th European Colloquium of Arachnology, Århus 17-22 July 2000. pp. 57-64.

Sunderland, K. D. 1999. Mechanisms underlying the effects of spiders on pest populations. Journal of Arachnology 27: 308-316.

Tahir, H. M., Butt, A. and Sherawat, S. M. 2009. Foraging strategies and diet composition of two orb web spiders in rice ecosystems. Journal of Arachnology 37:357–362.

Tsutsui, M. H., Tanaka, K., Baba, Y.G. and Miyashita, T. 2016. Spatio-temporal dynamics of generalist predators (*Tetragnatha* spider) in environmentally friendly paddy fields. Applied Entomology and Zoology 51:631-640

Turnbull, A.L. 1973. Ecology of the true spiders (Araneomorphae). Annual Review of Entomology 18: 305-348.

Venturino, E., Isaia, M., Bona, F., Chatterjee, S. and Badino, G. 2008. Biological controls of intensive agroecosystems: wanderer spiders in the LangaAstigiana. Ecological Complexity5:157–164.

World Spider Catalog (2017). World Spider Catalog. Natural History Museum Bern. http://wsc.nmbe.ch, version 18.5 (accessed July 25, 2017).

Yoshida, M. 1987. Predatory behavior of *Tetragnatha praedonia* (Araneae: Tetragnathidae). ACTA Arachnology. 35: 57-75.

APPENDICES

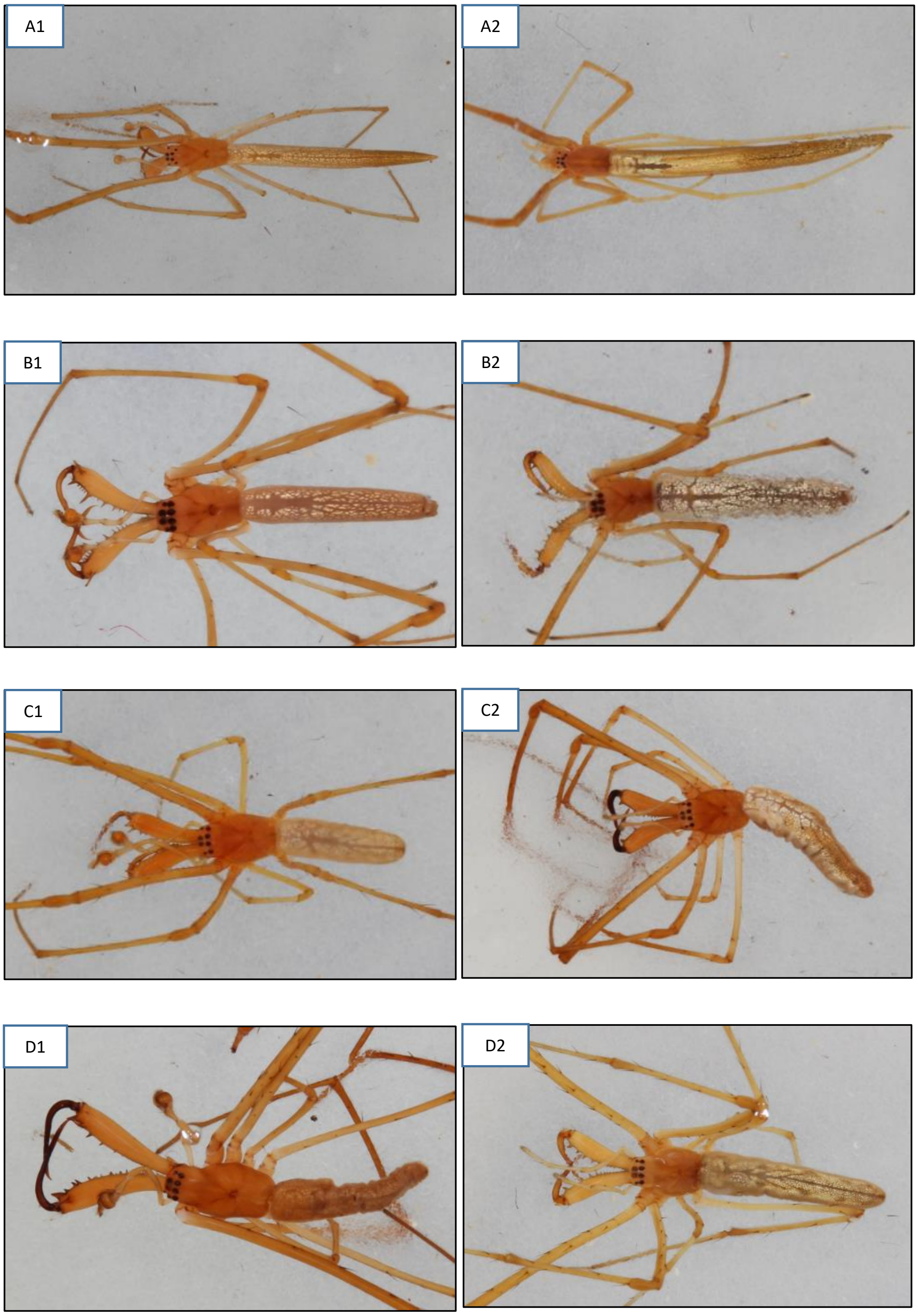

A

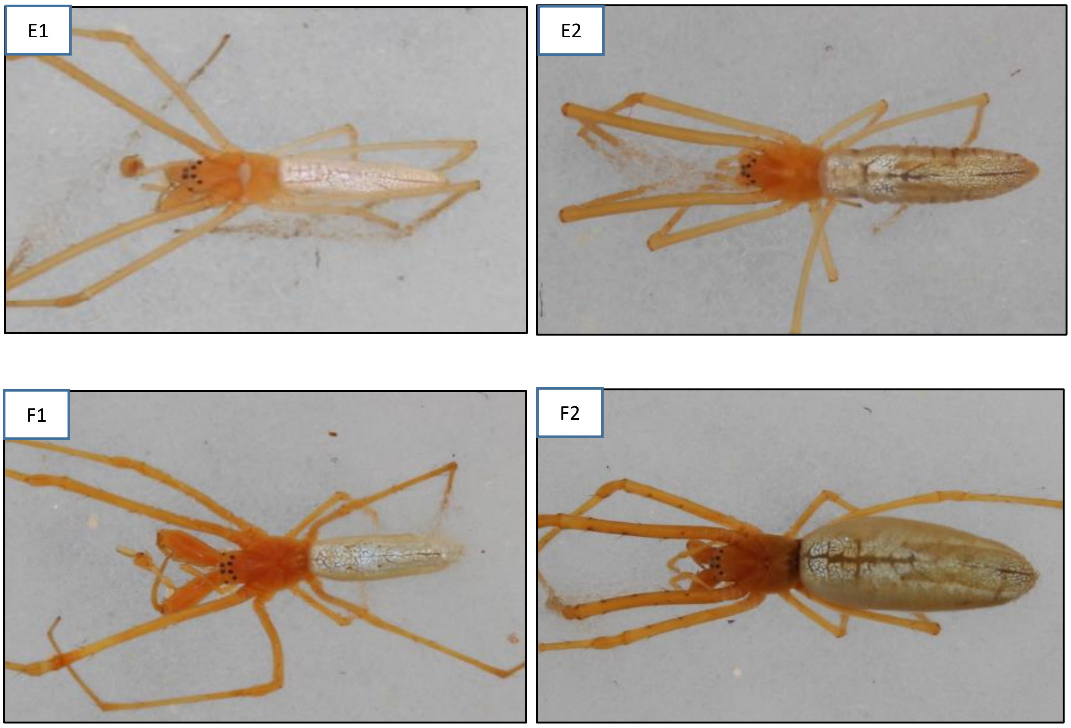

B


C

Appendix 1. Four stages of rice plant

A. Vegetative Growth stage
B. Reproductive stage
C. Ripening stage
D. After-harveesting stage


A1
A2
B1
B2
C1
C2
D1
D2



Appendix 2. Figures of six species of *Tetragnatha* spider.

A. *Tetragnatha javana* (Thorell, 1890) (A1) male (A2) female

B. *Tetragnatha maxillosa* (Thorell, 1895) (B1) male (B2) female

C. *Tetragnatha nitens* (Audouin, 1826) (C1) male (C2) female

D. *Tetragnatha mandibulata* (Walckenaer, 1842) (D1) male (D2) female

E. *Tetragnatha virescens* (Okuma, 1979) (E1) male (E2) female

F. *Tetragnatha vermiformis* (Emerton, 1884) (F1) male (F2) female

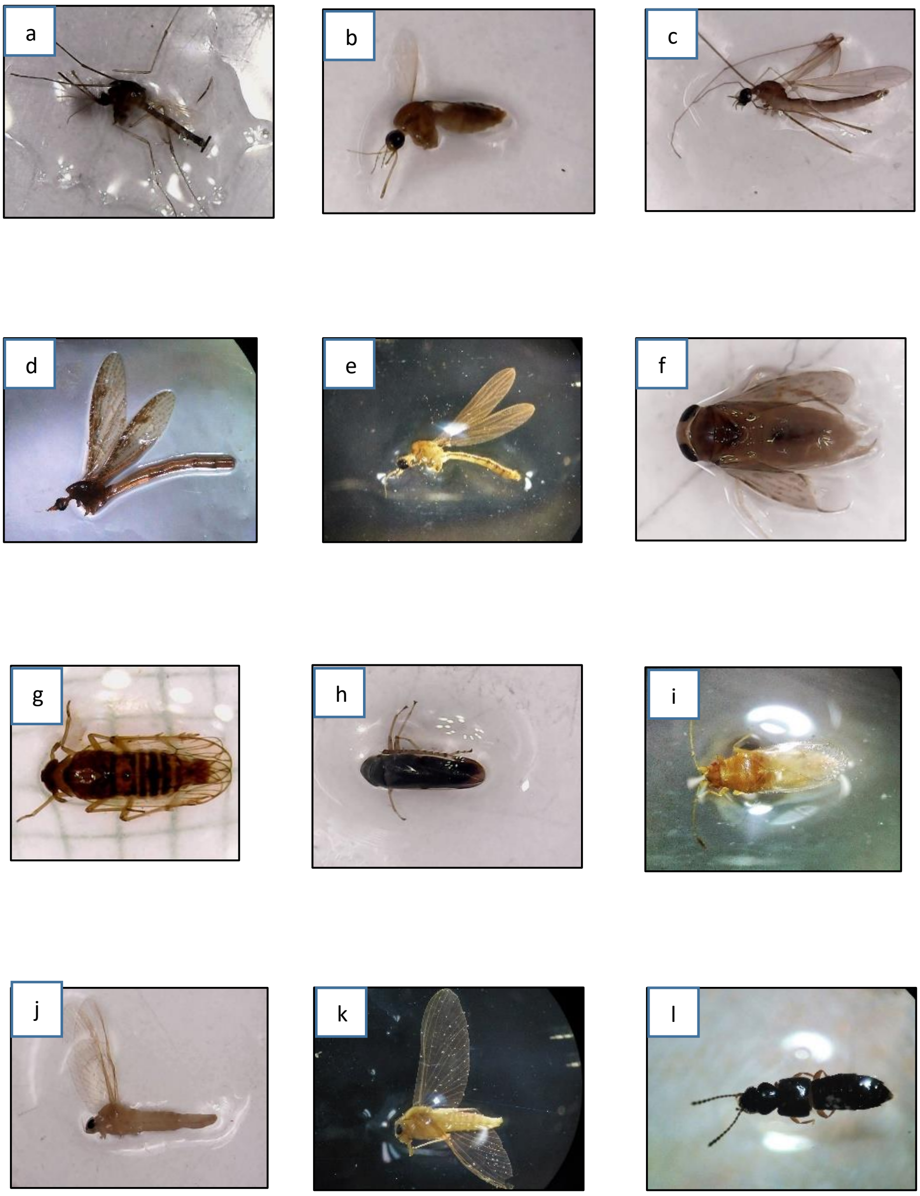
Appendix 3. Number of *Tetragnatha* spider in each rice stage by visual searching method

stage	site	species	total
Vegetative growth stage	1	*T. javana*	0
		T. maxillosa	1
		T. mandibulata	3
		T. nitens	2
		T. virescens	0
		T. vermiformis	0
	2	*T. javana*	0
		T. maxillosa	3
		T. mandibulata	1
		T. nitens	1
		T. virescens	4
		T. vermiformis	0
	3	*T. javana*	4
		T. maxillosa	3
		T. mandibulata	1
		T. nitens	1
		T. virescens	0
		T. vermiformis	0
Reproductive stage	1	*T. javana*	15
		T. maxillosa	1
		T. mandibulata	3
		T. nitens	2
		T. virescens	1
		T. vermiformis	0
	2	*T. javana*	9
		T. maxillosa	12
		T. mandibulata	3
		T. nitens	4
		T. virescens	4
		T. vermiformis	1
Reproductive stage (continued)	3	*T. javana*	10
		T. maxillosa	8
		T. mandibulata	0
		T. nitens	2
		T. virescens	2
		T. vermiformis	0

stage	site	species	total
Ripening stage	1	*T. javana*	4
		T. maxillosa	1
		T. mandibulata	1
		T. nitens	1
		T. virescens	0
		T. vermiformis	0
	2	*T. javana*	4
		T. maxillosa	2
		T. mandibulata	1
		T. nitens	1
		T. virescens	0
		T. vermiformis	0
	3	*T. javana*	3
		T. maxillosa	9
		T. mandibulata	0
		T. nitens	2
		T. virescens	0
		T. vermiformis	0
After harvesting stage	1	*T. javana*	2
		T. maxillosa	0
		T. mandibulata	0
		T. nitens	0
		T. virescens	0
		T. vermiformis	0
	2	*T. javana*	2
		T. maxillosa	1
		T. mandibulata	0
		T. nitens	0
		T. virescens	0
		T. vermiformis	0
After harvesting stage (continued)	3	*T. javana*	2
		T. maxillosa	0
		T. mandibulata	0
		T. nitens	0
		T. virescens	0
		T. vermiformis	0

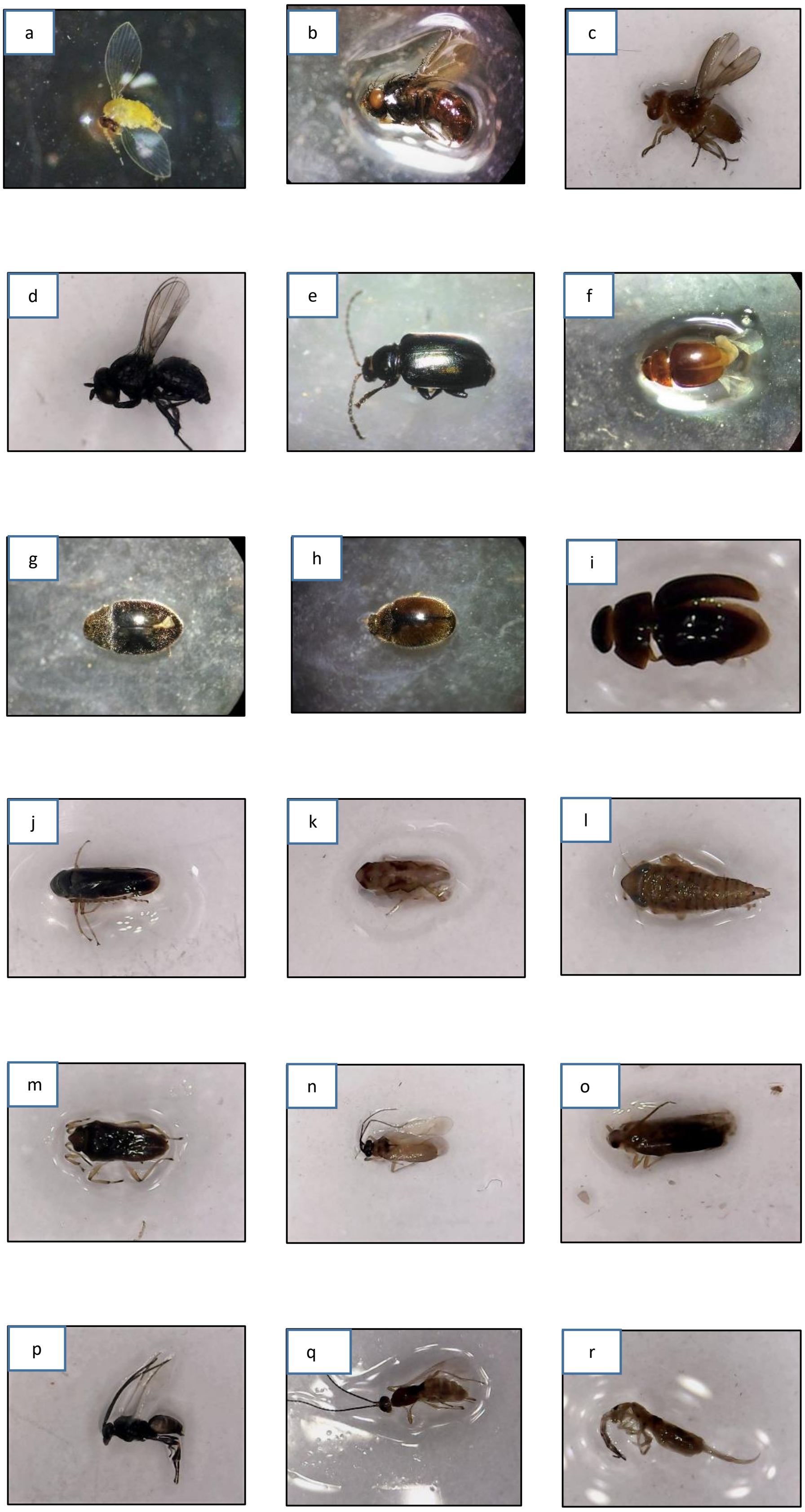
Appendix 4. Percentage of prey in each family each stage of rice (A=Vegetative growth stage, B=Reproductive stage, C=Ripening stage and D=After harvesting stage)

Order	Main family	Prey	A	B	C	D
Diptera	Chironomidae	Available	46.4	22.23	0.85	14.16
		Captured	56.2	29.23	14.34	33.33
	Cecidomyiidae	Available	0	0.48	0.05	1.58
		Captured	2.4	1.01	7.17	16.67
Hemiptera	Corixidae	Available	1.5	1.02	0.33	0.3
		Captured	28.1	50.68	0	0
	Cicadellidae	Available	2.8	12.1	14.64	2.87
		Captured	0	0.17	0	0
	Delphacidae	Available	0.5	0.61	0.38	0.79
		Captured	0	1.18	21.51	0
Lepidoptera	Pyralidae	Available	0.8	3.33	0.52	0
		Captured	0	0	0	0
Ephemeroptera	Baetidae	Available	0.1	0.82	0.24	0
		Captured	0	4.05	0	33.33
Orthoptera	Acrididae	Available	4.8	0.95	2.68	7.42
		Captured	0	0	0	0
Collembola	Entomobryidae	Available	0	0	20.3	31.8
		Captured	0	0	0.17	0
Others	other families	Available	43.1	58.47	60.02	41.06
		Captured	13.4	13.68	57.18	16.67



Appendix 5. Figures of common captured prey of *Tetragnatha* spider

a-e	Order	Diptera
f- i	Order	Hemiptera
j-k	Order	Ephemeroptera
l	Order	Coleoptera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Appendix 6. Figures of available prey in rice field

a-d	Order	Diptera
e-i	Order	Coleoptera
j-n	Order	Hemiptera
o	Order	Lepidoptera
p-q	Order	Hymenoptera
r	Order	Entomobryomorpha (Class Collembola)

Appendix 7. Ivlev index (IE) in each family each stage of rice

*** which calculated from IE = (r-p)/(r+p) (r = the percentage contribution of individuals from a prey family to the captured prey composition, p = the percentage contribution of the same prey family to the available prey composition)

family	Vegetative			Reproductive			Ripening			After harvesting		
	p	r	IE	p	r	IE	p	r	IE	p	r	IE
Chironomidae	46.4	56.2	0.1	22.2	29.2	0.1	0.8	14.3	0.9	14.2	33.3	0.4
Corixidae	1.5	28.1	0.9	1.0	50.7	0.9	0.3	0	-1	0.3	0	-1
Cecidomyiidae	0	2.4	1	0.4	1.0	0.3	0.0	7.1	1	1.5	16.6	0.8
Coenagrionidae	1.5	2.4	0.2	1.0	1.0	-0	0.4	0	-1	0	0	-
Ephemerellidae	0	1.2	1	0.2	1.7	0.7	0	3.5	1	0	0	-
Baetidae	0.1	0	-1	0.8	4.1	0.6	0.2	0	-1	0	33.3	1
Delphacidae	0.5	0	-1	0.6	1.2	0.3	0.3	21.5	1	0.7	0	-1
Notonectidae	0	0	-	0	1.9	1	0	0	-	0	0	-
Tipulidae	0	0	-	3.1	1.9	-0.2	0.9	3.5	0.6	0.8	0	-1
Cicadellidae	2.8	0	-1	12.1	0.2	-0.9	14.6	0	-1	2.8	0	-1
Pyralidae	0.8	0	-1	3.3	0	-1	0.5	0	-1	0	0	-
Acrididae	4.8	0	-1	0.9	0	-1	2.6	0	-1	7.4	0	-1
others	41.6	9.8	-0.6	54.1	7.3	-0.8	78.9	50.2	-0.2	72	16.6	-0.6

Appendix 8. Number of plant contacted to the pole (vegetative complexity)

point	Vegetative			Reproductive			Ripening		
	< 0.5	> 0.5	total	< 0.5	> 0.5	total	< 0.5	> 0.5	total
1	2	0	2	3	1	4	4	4	8
2	3	1	4	5	2	7	7	5	12
3	4	1	5	2	1	3	5	4	9
4	2	1	3	2	3	5	3	4	7
5	2	0	2	2	2	4	5	4	9
6	1	2	3	3	4	7	4	2	6
7	3	1	4	1	4	5	4	2	6
8	1	0	1	5	2	7	4	4	8
9	6	0	6	3	0	3	5	1	6
10	5	1	6	1	2	3	3	2	5
11	3	2	5	4	3	7	2	4	6
12	1	1	2	3	2	5	4	2	6
13	2	0	2	3	5	8	3	4	7
14	2	1	3	2	4	6	5	4	9
15	2	1	3	3	5	8	6	5	11
16	1	0	1	3	1	4	6	3	9
17	1	3	4	3	5	8	7	5	12
18	2	2	4	2	2	4	7	2	9
19	1	1	2	3	4	7	12	1	13
20	2	1	3	4	4	8	3	3	6
21	1	1	2	3	3	6	11	3	14
22	2	0	2	3	2	5	5	3	8
23	3	0	3	3	1	4	4	2	6
24	1	0	1	4	4	8	3	2	5
25	2	1	3	5	1	6	3	3	6
26	2	1	3	3	3	6	4	4	8
27	2	1	3	3	3	6	5	2	7
28	1	0	1	2	1	3	3	1	4
29	2	1	3	1	3	4	3	4	7
30	3	1	4	1	2	3	3	5	8
Average	2.17	0.83	3.00	2.83	2.63	5.47	4.77	3.13	7.90

VITAE

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List of Publication and Proceeding

Saksongmuang, V. & Bumrungsri, S. 2017. Population dynamics and prey composition of *Tetragnatha* spp. in rice field of southern Thailand. Association for Tropical Biology and Conservation (ATBC), Asia-Pacific Chapter Meeting 2017. 25-28 March 2017, Xishuangbanna, China.

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