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Preying ability of spiders *Oxyopes* sp. and *Pardosa* sp. on four prey types of insect pests under laboratory conditions

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The aim of this research was to investigate the preying ability of two predators: lynx spider (*Oxyopes* sp.) and wolf spider (*Pardosa* sp.) on larva of *Spodoptera exigua* (Hubner), nymph of *Nesidiocoris tenuis* (Reuter), imago of *Empoasca* sp., and imago *Bemisia* sp. The study was conducted using a complete randomized block design. Preying ability of *Oxyopes* sp. on imago of *Bermisia* sp. was the highest, followed by *Pardosa* sp. on imago of *Bemisia* sp., *Oxyopes* sp. on nymph of *Empoasca* sp., *Pardosa* sp. on imago of *Empoasca* sp., *Oxyopes* sp. on larva of *S. exigua*, *Pardosa* sp. on nymph of *N. tenuis*, *Oxyopes* sp. on nymph of *N. tenuis,* and the lowest was *Pardosa* sp. on larva of *S. exigua*. There was no difference of preying ability between *Oxyopes* sp. and *Pardosa* sp. for the same species of insect prey. Difference of preying ability of these two predators only observed on different insect species. Likewise, there were difference in preying ability of each predator themselves on tested insects.

Keywords: spider, preying ability, insect pest, predation

INTRODUCTION

Nowadays there is a tendency on sustainable ecological approach (ecological sustainability) to reduce the use of pesticides on the agro-ecosystem, thereby increasing interest in biological agents such as spiders, which are potential as a biological control agents. Spiders are predators of insect pests, which are very important and abundant in terrestrial ecosystems throughout the world (Wise, 1993; Jeyaparvathi et al., 2013; Tahir et al., 2014).

Natural or biological control of the pest is one way to reduce the risks to human health and environmental damage. Spiders (Araneae) re biological agents which are considered potent in controlling insect pests in agricultural ecosystems. There are 44.906 species found throughout the world and are found in almost all types of habitats (Platnick, 2014). Spiders are the main predators of insects and also eat many other organisms well (Helsdingen, 2011).

Many studies show that spider can substantially decrease the density of prey. Lang et al., (1999) found that spiders on corn plants reduce the population of leafhoppers (Cicadellidae), thrips (Thysanoptera), and aphid (Aphididae). There are three types of spiders which are abundantly found in wheat crops: *Pardosa Agrestis* and two species of Linyphiidae. The results of studies in the laboratory revealed that these spiders reduced 34-50% of aphid populations (Marc et al., 1999). Both web-weaver and hunter spiders can limit the population of phytophagous Homoptera, Coleoptera and Diptera on agricultural crops in Tennesseee (Riechert and Lawrence, 1997). Of total spider species studied by Sankari and Thiyagesan (2010) on the plant *Solanum melongena* and

Trichosanthes anguina, all demonstrated effective pest populations stabilization. Pests that attacked cotton crops in Tamil Nadu, India, were able to be controlled by four dominant species of spiders (Jayaparvathi et al., 2013). Spiders as predators of herbivorous insects also effectively protected apple crops, including the beetle *Anthonomus pomorum* and the larvae of the family Tortricidae (Marc and Canard, 1997). Wolf spider also reduced the density of awl-suckers herbivores (Delphacidae and Cicadellidae) on rice crops in the tropics (Fagan et al., 1998). The spiders which were able to reduce the population of herbivores may be limited by the availability of food and competition in some agro-ecosystems (Sunderland, 1999).

Various studies have also shown that insect populations increased significantly if detached from spider predation. Riechert and Lawrence (1997) reported that if the spiders were taken out of the experimental plots on the farm, the number of herbivorous insects increased significantly, compared to the plots where the spiders were always kept inside. In Tennessee, the plots in the vegetable garden where the spider disappeared, the number of pests increased, compared with if the spiders were always there (Riechert and Bishop, 1990). All of these studies clearly showed that spiders are often prey on many species of crop pests of the Lepidopteran and Heteropteran and various aphids, leafhoppers, treehoppers, and plant hoppers, which are potentially dangerous, sucking nutrients from the plant, as well as vectors of disease (Nyffeler and Sunderland, 2003).

Studies conducted on the cotton crop in Texas, however, showed that the percentage of the aphid diet *Oxyopes salticus* was low compared to other groups of potential prey (Nyffeler et al., 1987). this illustrates that the spiders avoid aphid as prey. The quality of some groups of spiders prey (such as aphids) is very low compared to other (such as Collembola, Diptera), so in general, basically this depends on the quality of the food in the prey species (Toft, 2013). Hunter spiders were considered as predators which are important for pests at various stages of plant (Young, 1989; Nyffeler and Sunderland, 2003). This spider moved on actively to foraging on larvae and adults of Lepidoptera and Heteroptera. Lycosidae was often seen attacking larval pests of the Order Lepidoptera on corn (Brust et al., 1986).

Spiders are very abundant and prey on insects on a variety of habitats, thereby playing an important role as predators in the agro-ecosystem, forest crops (agroforestry), and other terrestrial ecosystems. Spiders are one group of generalist predators that need to be developed, because it is more efficient, sustainable and low-input farming systems. This study was aimed to determine the preying ability of both genera of spider hunter: *Oxyopes* and *Pardosa* that have different ecological guilds on insect pest larvae of *Spodoptera exigua* (Hubner), nymphs of *Nisiodiocoris tenuis* (Reuter), imago of *Empoasca* sp., and imago of *Bemisia* sp.

MATERIALS AND METHODS

The hunter spiders *Oxyopes* sp. (family Oxyopidae) and *Pardosa* sp. (family Lycosidae) were obtained from Tomohon city and Minahasa regency. In both locations there are various types of crops such as paddy rice, corn, beans, vegetables including tomatoes, scallion, onion, peppers, and cabbage. This experiment was conducted at Laboratory of Plant Pest and Disease, from May to November 2016. Those spiders have different strategy in finding prey (ecological guild) (Uetz et al.,1999; Cardoso et al., 2011). *Oxyopes* sp. is a stalker which dwells and hunts for prey among the stalks of plants, while *Pardosa* sp. is a ground runner which inhabits and hunts for prey on the ground and also climbs to the leaves on low vegetation. The spiders were kept in plastic containers with diameter of 10 cm and height of 19 cm, and covered by gauze.

Containers for *Oxypes* sp. were supplied with twigs of fresh plants, while for *Pardosa* sp. were supplied with soil about 1 cm thick and dried leaves. Into each of these containers, preys with smaller sizes were added. The preys were caught in agricultural area and reared in laboratory. The mean length of body of *Oxyopes* sp. and *Pardosa* sp. were 6.60-8.50 and 4.90-6.70 mm, respectively. Insect pests used as prey in this experiment are common or predominantly pests, both larvae/nymph and imago, found in agricultural lands planted with tomato, kidney beans, and scallion. Four species of pests used in this experiment were larva of *S. exigua*, nymph of *N. tenuis*, imago of *Empoasca* sp., and imago of *Bemisia* sp. (Table 1 and Figure 1). Insect pests were captured directly or using insect nets and aspirators. They were kept inside plastic jars containing fresh leaves in accordance with the respective food materials. Wet sponges were put on the base of the jar to prevent leaves from wilting.

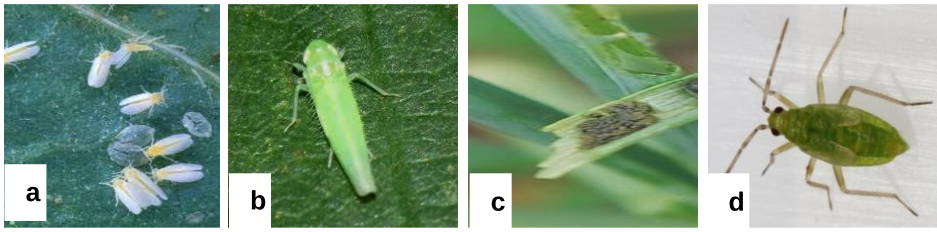

Figure 1. (a) *Bemisia* sp., (b) *Empoasca* sp., (c) *S. exigua*, dan (d) *N. tenuis.*

Table 1. Types of insect pest used as preys, their stadia, ordo/family, lenght of body, and their sources. N is the number of sample per prey (individual).

Species/genus of prey	Stadia	Order/Family	Length of body (mm)	N	Souces
***Bemisia* sp.**	Imago	Homoptera, Aleyrodidae	1.0-1.5	120	Bean,tomato
***Empoasca* sp.**	Imago	Homoptera, Cicadellidae	2.0-2,5	80	Bean
Nisiodiocoris tenuis	Nimfa	Hemiptera, Miridae	2.0-2.5	80	Tomato
Spodoptera exigua	Larva	Lepidoptera, Noctuidae	4.0-5.0	80	Scallion

Completely randomized design was used in this experiment. There were four species of preys with four replications. Each prey was added into each 350 ml plastic jars as testing places for predation. Into each bottle, one type of spider was supplied according to the design and covered with gauze. Before the experiment, *Oxyopes* and *Pardosa* were not fed for 24 hours. The preying ability of those spiders was recorded for 24 hours after being introduced into the jar. The data were collected and analyzed using one-way ANOVA test and furthered analyzed with Scheffe test to determine the differences in the ability to prey on the confidence level of 95%. Analysis was conducted using SPSS v.21

RESULTS

The preying ability of *Oxypes* sp. on imago of *Bemisia* sp. is the highest (13.00±0.91), followed by *Pardosa* sp. on imago of *Bemisia* sp. (12.00±1.1), *Oxyopes* sp. on nymph of *Empoasca* sp. (mean 8.25±0.85), *Pardosa* sp. on imago of *Empoasca* sp. (7.50±0.65), *Oxyopes* sp. on larvae of *S. exigua* and on nymph of *N. tenuis* (5.50±0.65 respectively), *Oxyopes* sp. on nympgh of *N. tenuis* (5,25±1,26) and the lowest is *Pardosa* sp. on larva of *S. exigua* (5.00±0.71) (Table 2).

The ANOVA analysis on the preying ability of the spiders *Oxyopes* sp. and *Pardosa* sp. on their respective insect preys showed significant difference ($F_{7.24}$= 37.910; p=0.00). However, there is no significant difference on the preying ability between *Oxyopes* sp. and *Pardosa* sp. on the same insect species (Figure 2).

The preying ability of *Oxyopes* sp. on *N. tenuis* and *S. exigua* (p=1.00), and also *Empoasca* sp. (p=0.329) showed no difference, while there was significant difference on *Bemisia* sp. (p=0.00). Likewise, the preying ability of *Pardosa* sp. on *S. exigua*, *N. tenuis* (p=1.00) and *Empoasca* sp. (p= 0.56) showed no significant difference, while there was a significant difference on *Bemisia* sp. (p=0.00). There was no significant difference on preying ability of *Oxyopes* sp. and *Pardosa* sp. on the same insect pests *N. tenuis* (p= 1.00), *Bemisia* sp. (p= 0.97), *S. exigua* (p= 1.00), and *Empoasca* sp. (p= 0.99).

The preying ability of these two predators on imago of *Bemesia* sp. was significantly different from *N. tenuis* (p= 0,00), *S. exigua* (p= 0, 00), and *Emposca* sp. (p= 0,00) which were preyed by *Oxyopes* sp., as well as *Pardosa* sp. on *N. tenuis* (p= 0,00), *S. exigua* (p=0,00), and *Empoasca* sp.

(*p*=0,01). These two predators also showed significant difference between *Oxyopes* sp. on *Empoasca* sp. and *Pardosa* sp. on *S. exigua* (*p*=0.027).

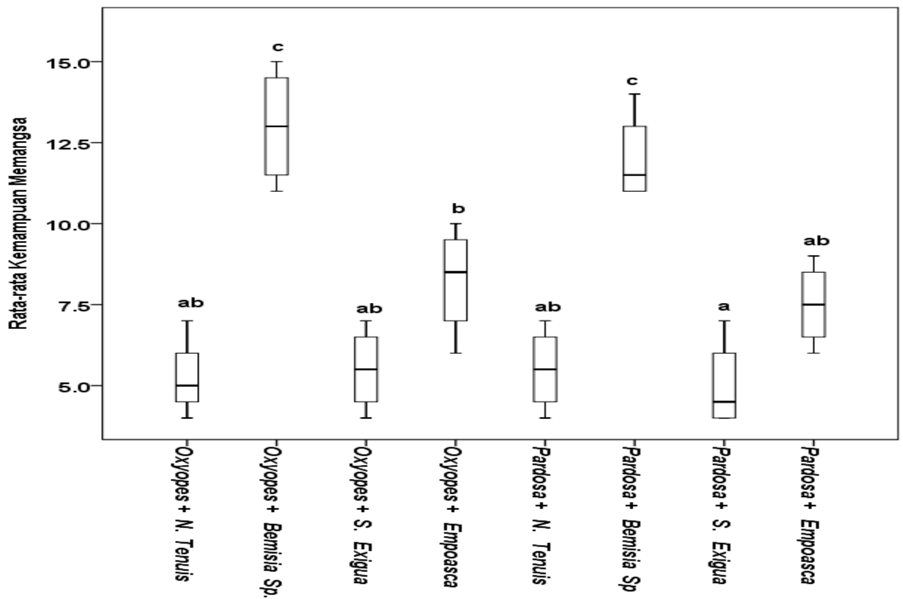

Figure 2. The preying ability of *Oxyopes* and *Pardosa* on nymph of *N. teuis*, larvae of *S. exigua,* imago of *Ecompoasca* sp., and imago of *Bemisia* sp (mean ± SE; n=16 individuals for *Oxyopes* and *Pardosa*, respectively). Diffent letters in the picture indicates a significant difference using one-way ANOVA and Scheffe test at 95% confidence level.

Table 2. The average preying ability of *Oxyopes* and *Pardosa* on nymph of *N. tenuis,* larva of *S. exigua,* imago of *Empoasca* sp., and imago of *Bemisia* sp. (± S.E)

Spiders (predator)	Insect pests (prey)	Number of preys per replication (n)	Average of prey fed by spiders
***Oxyopes* sp.**	*Bemisia* sp.	15	13.00±1.82
***Pardosa* sp.**	*Bemisia* sp.	15	12.00±1.41
***Oxyopes* sp.**	*Empoasca* sp.	10	8.25±1.71
***Pardosa* sp.**	*Empoasca* sp.	10	7.50±1.29
***Oxyopes* sp.**	*S. exigua*	10	5.50±1.29
***Pardosa* sp.**	*N. tenuis*	10	5.50±1.29
***Oxyopes* sp.**	*N. tenuis*	10	5.25±1.26
***Pardosa* sp.**	*S. exigua*	10	5.00±1.41

DISCUSSION

The difference of preying ability between two tested spiders occured because of suitability and the difference in size of the prey, where *Bemisia* sp. is relatively smaller than other prey. Most spiders eat preys that are relatively smaller than their size (Wise, 1993). Other experiment on preying/feeding of spiders on crickets showed that the optimum length of prey ranged from 50% to 80% of the length of the spiders themselves (Nentwig, 1987; Maloney et al., 2003). Overall, individual spider that dominates the agricultural crop acreage is small, and their main prey are smaller organisms (<4 mm) (Young dan Edwards, 1990). *Oxyopes javanus* is one of the dominant spiders in paddy crop in Punjab, which reaches approximately 13% of the total spiders (Tahir and Butt, 2008; Butt and Xaaceph, 2015). This spider eats prey with the size of 1-2.9 mm. This is the basis of the size of the prey, which is approximately equal to the rice plant hopper pest which is a diet of spider (Nyffeler et al., 1987).

The significant difference of the preying ability of *Oxyopes* sp. and *Pardosa* sp. on their respective insect preys demonstrates the preying of both predators in the same limited environmental conditions. This also may be caused by the difference in size between the two spider's preys, or also because of the specificity of prey (Table 1).

Although spiders are known as generalist predators or polyphagous, they also have particularity of prey. This prey specificity may occur due to any kind of spider requires different composition and proportion of nutrients. Prey selection is very important for individual fitness, therefore the predators will select exposed preys based on differences in quality. Kosiba et al., (2012), which examined the effectiveness of eating of *Megaphobema mesomelas* (Araneae, Theraphosidae) on two types of prey, showed that this spider effectively ate more crickets than beetles. The results of observations of Líznarová and Pekár (2015) revealed that even though spiders prey on five type of invertebrate, but their predominant prey was ants. Laboratory experiment showed that *Oecobius maculatus* prey on three different type of insect with high probability on ants, and significantly more efficient in capturing and handling flies than ants. This commonly occurs if the spiders have a lot of prey, making it more selective (Riechert and Harp, 1987).

The preying ability of *Oxyopes* sp. and *Pardosa* sp. on *N. tenuis*, *S. exigua*, *Empoasca* sp., and *Bemisia* sp. showed that these two predators are generalist. According to Nyffeler (1999) that compared diets among hunter spider and web-weaver spiders, breadth analysis of their diet showed that the highest value was estimated five times higher than minimum value (B= 1.13 vs. 5.58), where in the indication was estimated from the differences of diet breadth among species. The B is the diversity of arthropod orders in the diet calculated using Inverse Simpson Index.

The hunter spiders such as Oxyopidae (*Oxyopes*) and Lycosidae are less specialist in their eating behavior (mean of diet breadth is 4.20±0.22), and for web-weaver spider, the mean is = 2.67±0.22. This calculation also shows that diet breadth of Oxyopidae (*Oxyopes*) is wider 4.42±0.59) than Lyosidae (3.90±0.20). This suggests that spiders generally have more than one type of prey. The diversity of the diet is very useful for optimizing the composition and balance of nutrients required for survival and reproduction (Greenstone, 1979; Uetz et al., 1992; Toft, 2013). Basically, the various groups of spiders eating the same order, but with different proportions (Nyffeler, 1999). Both *Oxyopes* sp. and *Pardosa* sp. could feed on larvae and adult insects. According to Jones-Walters (1993), generally the spider eats the larvae and adult insects. Observations about the spider eat the eggs still needs to be done, because the observation made in this study was only done in confinement.

The ability or potential to prey of the spiders in this experiment in the laboratory, both groups (*Oxyopes* sp. and *Pardosa* sp.) and as individuals on the four species of insect pests per day was quite high. However, in a field like the observation of Herlinda (2007), the average preying ability of *Pardosa pseudoannulata* on the brown plant hopper was 3.4 individuals per day. According Tulung (1999), *Psudoannulata pardosa* (Lycosidae) in the field was able to prey on one-tailed leafhopper nymphs per day on paddy rice ecosystem. Observation of Butt and Xaaceph (2015) described that there was a relation between prey and preying strategy of *Oxyopes javanus*, which is influenced by the density of prey and habitat complexity.

In the field, many factors affect the ability of prey such as the complexity of the the evironment, the movement and escaping behavior from other predators, the weather and the interaction between predator species. In addition, non-selective use of pesticides will have an impact on the rate of predation of spiders. Such factors need to be investigated further, because they can restrict the biopredation application in the field.

CONCLUSION

This study concluded that the preying ability of *Oxyopes* sp. and *Pordosa* sp. for the same of insect prey was the same. The different on preying ability of both spiders was observed only on different insect species.

CONFLICT OF INTEREST

The authors declared that present study was performed in absence of any conflict of interest.

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AUTHOR CONTRIBUTIONS

VVM designed and performed the experiments, as well as wrote the manuscripts. JBK collected the samples in the fields, performed the experiments, and conducted the data analysis. TET reviewed the manuscript. All authors read and approved the final version.

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