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Diversity of Spider Species in Some Agricultural Crops in North Sulawesi, Indonesia

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Abstract— Diversity and abundance of spider community is generally determined by the complexity of the structure of the plant and their environmental conditions. We have examined this relationship in four habitat types of agricultural crops, namely tomato, kidney bean, maize and shallot in Tompaso and Langowan regions of Minahasa Regency, North Sulawesi. We found the diversity of spider species in tomato was more than in maize and shallot, but not significantly different from in kidney bean. Likewise the spider species diversity on the kidney bean was not significantly different from the maize, but significantly different from the shallot. Spider species diversity was found highest in tomato, and then kidney bean, maize, and shallot, consecutively. Spider species richness in tomato and kidney bean was not significantly different, and the similar was between maize and shallot, but that in tomato and kidney bean was significantly different from maize and shallot.

Index Terms— Agro ecosystem, biocontrol, pest, Araneae, diversity, Minahasa, North Sulawesi.

1 Introduction

INTENSIVE use of synthetic pesticides has led to a negative reception of conventional farming systems, due to its negative impacts on the environment and human health. This turns all parties involved to a more environmentally friendly pest management systems that employ biological substances and processes. This natural control is an implementation of an ecological concept known as "community stability" that takes benefits of high biodiversity, where pests present with their natural enemies [1].

Spiders (Araneae) are generalist predators and one very potential biological agent in controlling insect pests in agricultural ecosystems [2, 3]. Spiders contribute immensely to the biodiversity in the agro-ecosystem and play a very important component in natural pest control [4]. As generalist predators, spiders are considered more efficient than the specialist predators to suppress pest habitats [5-7]. Generalist predators can live alternative preys [8]. Many studies showed that the spiders can very significantly reduce pest population density, such as leafhoppers (Cicadellidae), thrips (Thysanoptera), and aphis (Aphidae). For instance, *Pardosa agrestis* (Westring) and two species of Linyphidae could reduce aphid population by 30-50% in the laboratory [2, 9], and wolf spiders could reduce population density of Delphacidae and Cicadellidae on rice [10].

Biodiversity of spider species in natural ecosystems, including agriculture was high [11-13]. Spider community is closely related to the characteristics of the plant community where they live [14]. Suana *et al*. [15] stated that the structure of the landscape, habitat type, period of plant growth also play a role in the diversity of the spider species. Family of spiders that are often found in agro-ecosystems and play an important role in the natural control of insect pest species are members of the Araneidae, Linyphiidae, Lycosidae, Oxyopidae, Salticidae, Tetragnatidae, and Thomisidae [16].

Study on spider communities in agroecosystems in North Sulawesi is very rarely done. Taulu and Polakitan [17] in their study found 12 spiders of Linypiidae, Theridiidae, Salticidae, Araneidae, Clubionidae, Tetragnathidae, and Oxyopidae species on soybean plant canopy in the village of Kamanga, North Sulawesi. Agricultural landscape in Minahasa regency, especially in the areas of Langowan and Tompaso are heterogeneous and the crops cultivated in the areas generally are food crops and vegetables. In such agricultural ecosystems, temporal changes are frequent, as well as plant characteristics, cropping patterns, and environments. This effects on the abundance, diversity, and richness of the spider community that can be considered in the design of plant pest management strategies. In this manuscript we report the spider diversity in tomato, maize, kidney bean and shallot plants, as well as their ability to prey in the study area in North Sulawesi.

2 Materials and Methods

2.1 Time and Place of Study

The study was conducted during the period of January to June 2012 in the villages of Tempok, Tompaso 2, Kamanga, and Tumaratas within the agro-industry areas of Langowan and Tompaso, Minahasa Regency, North Sulawesi Province, Indonesia (situated approximately 600 m above sea level). The observations were conducted in four habitat types of agricultural crops, i.e. maize (*Zea mays* L.), kidney bean (*Vigna angularis* (Wild)), tomato (*Lycopersicum esculatum* Mill.), and Shallot (*Allium fistolosum* L). Cultivation techniques employed the local farmers's ones.

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TABLE 2.1
LIST OF SPIDERS COLLECTED FROM THE FOUR HABITAT TYPES OF FIELD CROPS: TOMATO, KIDNEY BEAN, MAIZE, AND SHALLOT. NUMBERS IN PARENTHESES ARE THE ABUNDANCE OF INDIVIDUALS

Family	Tomato		Kidney bean		Maize		Shallot	
	Genera	Species	Genera	Species	Genera	Species	Genera	Species
Araneidae	6	11 (51)	5	7 (30)	5	7 (28)	4	6 (18)
Clubionidae	1	2 (4)	1	1 (3)	3	4 (9)	2	2 (5)
Linyphiidae	2	3 (8)	1	2 (7)	1	1 (4)	1	1 (3)
Lycosidae	3	7 (54)	3	8 (58)	4	7 (49)	3	6 (36)
Mitidae	3	5 (24)	4	7 (44)	3	6 (16)	1	3 (15)
Oxyopidae	1	2 (5)	1	2 (10)	0	0	1	1 (3)
Salticidae	5	5 (8)	3	3 (7)	1	1 (2)	2	2 (5)
Tetragnathidae	1	2 (10)	1	3 (11)	1	4 (12)	1	3 (8)
Theridiidae	5	10 (29)	5	8 (18)	4	6 (14)	2	3 (13)
Thomisidae	1	1 (2)	1	1 (2)	1	1 (2)	0	0
Zodariidae	2	3 (7)	2	3 (6)	2	2 (4)	2	3 (4)
Total	30	51 (202)	27	45 (196)	25	39 (140)	19	30 (110)

2.2 Sampling, Identification and Abundance Calculation of Spiders

We determined three zones in each habitat type and a plot size of 2.5 × 2.5 m2 was set up each in the four corners of each zone for sample collection, totalling 12 plots in each habitat type and 48 plots for all four habitat types. A trap method was employed to catch ground crawling spiders and a direct capture method (hand-picking method) to catch spiders above ground and on the plants.

Plastic traps (made from 240-mL plastic cups) were planted in soil to surface level, then filled with 50% alcohol and soapy water (Pearce, et al. 2004). A trap was installed at the four maizeers of each habitat type. The sample collections were done after 2 × 24 hours of installation for four times. The spiders trapped were collected and put into collection bottles containing 70% alcohol for morphologic identification under a microscope and counting using the determination key of Barrio and Litsinger [18] and Roberts [19], and illustrated key of Stenchly key [20, 21]. The identifications were for the family, genus, and species.

2.3 Diversity, Richness, Distribution Evenness and Guild of Spiders

Shannon-Wiener index (H'), Margalef richness index (R), and Evenness Index (E) were used to see the differences in the structure of spider community in the four habitat types of agricultural crops [22-24]. The data obtained were tested by one-way ANOVA followed by Scheffe test at 95% confidence level to determine the differences in diversity, richness and evenness of species of spider in the four plant habitat types.

The spider guild composition is a way to see the differences in the structure of spider communities from a variety of habitats. Spiders that were collected in this study were grouped into eight classification systems of spider guild proposed by Uetz *et al*. [25], namely (1) foliage runners: Scytodidae, Heteropodidae, and Clubionidae; (2) ground runners: Lycosidae, Tetrablemmidae, Oonopidae, Gnaphosidae, and Clubionidae; (3) stalkers: Oxyopidae and Slaticidae; (4) ambushers: Philodromidae and Thomisidae; (5) sheet-web builders: Hahniidae; (6) wandering sheet/web weavers Tangle: Linyphiidae and Theraphosidae; (7) orb-weavers: Araneidae, Tetragnathidae, and Uloboridae; (8) web space builders: Pholcidae and Theridiidae.

3 RESULTS AND DISCUSSIONS

3.1 Collection, Identification, and Abundance of the Spiders

The total collected spiders contained 648 individuals, consisting of 72 species, 36 genera, and 11 families with each habitat population as described in Table 2.1. Almost all the families of spiders were found in all habitats, except Thomisidae that was not found in Shallot and Oxyopidae that was not found in maize. There were various factors that might affect the variety of caught spiders, among others the active time of the spider, the sampling tool, the width sampling area, the characteristics of the habitat types and level of disturbance.

The most abundance spiders found in each habitat type were: tomato with Lycosidae (54 individuals), Araneidae (51), and Theridiidae (29); kidney bean with Lycosidae (58), Mitidae (44), and Araneidae (30); maize with Lycosidae (49), Araneidae (28), and Mitidae (16); and shallot with Lycosidae (36), Araneidae (18), and Mitidae (15) (see Table 1). Lycosidae was the most abundance in kidney bean than in other habitat types, and was also the most dominant in each habitat type. Lycosidae inhabits and hunts their prey on open ground, they also were found climbing on leaves, especially on low vegetation such as on the kidney bean. Rimbing and Memah [26] study on the abundance of predatory arthropods on soybean that taxonomically are similar to the kidney bean in North Minahasa found that Lycosidae (*Pardosa* spp.) abundance reached 34% and was the highest of all the predators collectied.

Araneidae is an orb-weaver spider found to be the second

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most dominant after the Lycosidae on tomato plants, and also the most abundance in this habitat. The Araneidae usually prefers constructing their web on the canopy structure of complex plants with relatively open branches or twigs. Generally they construct their webs on tomato vertically.

Mitidae also was a dominant spider, after Lycosidae, found in kidney bean plants and also the most abundance in this plant habitat. The Mitidae uses web to capture preys and generally prefers netting on the top of the canopy of low vegetation with relatively more dense foliage, as well as the close spacing. The Mitidae nets usually horizontal in shape.

Theridiidae also uses webs to capture preys. This spider was third in dominance in tomato and the highest population in this habitat. The Theridiidae usually construct their webs in between the branches, twigs, and leaves. Russell-Smith & Stork [27] found that Theridiidae was abundant at all elevations in the tropical rain forest canopy in Dumoga-Bone National Park, North Sulawesi.

Differences in crop structure, size, number of leaves, twigs, branches, spaces in between branches, twigs, and leaves, and leaf and canopy shape affect the availability of species of the families of Lycosidae, Araneidae and Theridiidae. Leaf spiders tend to colonize the leaves with higher number of branches [28]. In this sense the tomato and kidney bean are more populated than the maize and shallot.

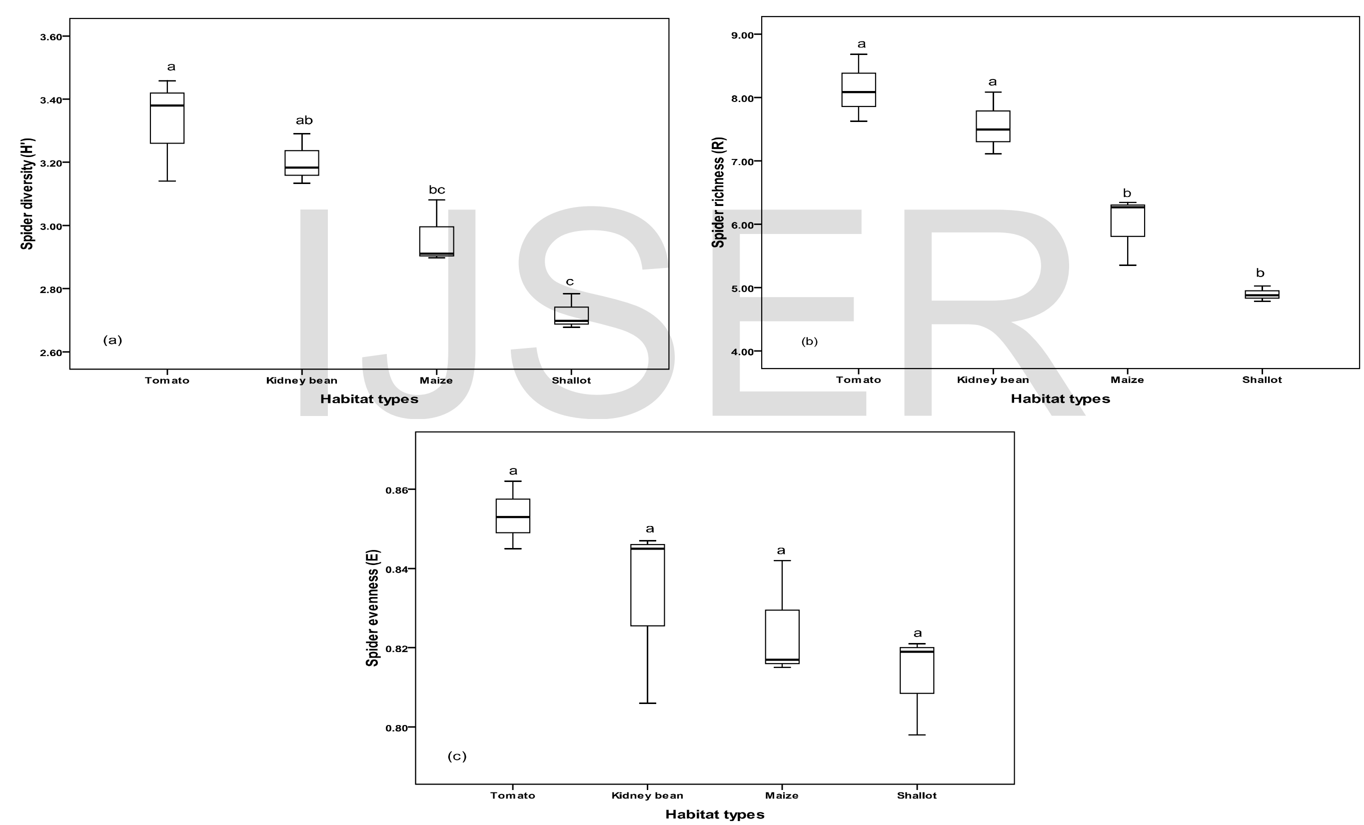

Fig. 2.1. Diversity (a), richness (b), and evenness (c) of spider species in 4 habitat types of crop (mean ± SE, *n* = 12). Different letters in the image represent significant differences.

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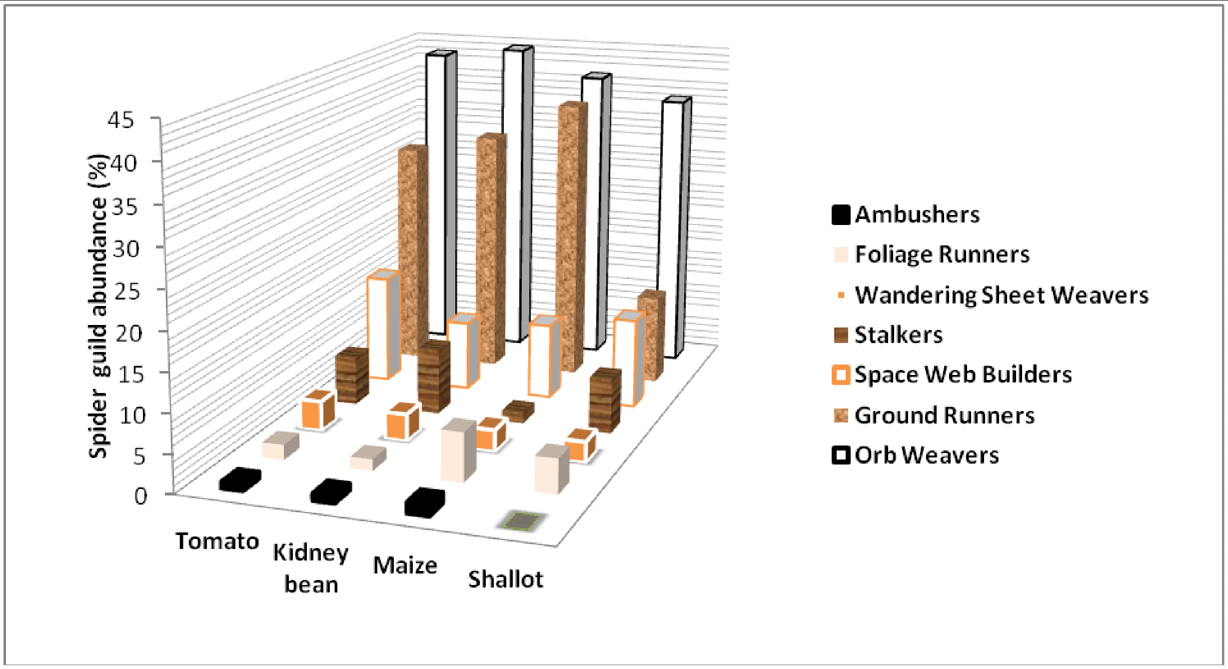

Fig. 2.2. Guild compositions of spiders collected from the 4 habitat types of crop field.

3.2 The Relationship of Habitat Structure with the Diversity, Richness, Distribution Evenness, and Guild Composition of Spider

There was a significant of the four habitat types on the diversity of the spider species ($F_{3,8}$ = 18,237, p = 0.001) and the richness of spider species ($F_{3,8}$ = 31,164, p = 0.000), but not on the distribution evenness of the spider species ($F_{3,8}$ = 3,527, p = 0.068) (see Fig. 2.1c).

The spider diversity in tomato was not significantly different from that in kidney bean (p = 0.067), but there was from maize (p = 0.02) and shallot (p = 0,01). The spider diversity in kidney bean was not significantly different from maize (p = 0.141), but was from shallot (p = 0.005). The diversity in maize and shallot was not significantly different (p = 0.134). The highest diversity was found in tomato (3.33 ± 0.09) followed by kidney bean (3.20 ± 0.05), maize (2.96 ± 0.06), and shallot (2.72 ± 0.03). There is no real difference between species richness profit spider on tomato and kidney bean (p = 0.545), but significantly different between maize (p = 0.003) and shallot (p = 0.00). The richness of spider species in kidney bean was significantly different from maize (p = 0.020) and shallot (p = 0.001). We found no significant different in the richness of spider species in maize and shallot (p = 0.106). The highest spider species richness was found in tomato (8.13 ± 0.31), followed by kidney bean (7.56 ± 0.28), maize (5.99 ± 0.32) and shallot (4.89 ± 0.07).

The absence of significant differences in spider species evenness among habitat types indicates that all species are similar in abundance. Based on the analysis of evenness index, the result was maximum and tends to decline toward zero as the relative abundance of a species that is not the same. The evenness index is independ on the number of species in the sample. This suggests that a few addition of any species will lead to major changes in the value of the evenness index.

Differences in abundance, diversity and richness of spider species in any habitat types are affected by various factors, such as habitat complexity. The four habitat types in the observation can be classified into two habitat groups: (1) plants with many (complex) branches are tomato and kidney bean, and (2) plants with simple branch are maize and shallot. Although the diversity of spider species were not significantly different between kidney bean and maize, but species richness and abundance were significantly different. This shows an association between the structural complexity of the plant to the species abundance, diversity and richness.

High density of leaves and branches, and more complex twigs in tomato and kidney bean make them good habitats for the canopy dweller spiders. The physical structure and the density of the plants will provide good living conditions for the spiders to construct webs, hiding place or shelter, prey availability, microclimatic conditions such as temperature and humidity, mating activity, and competition [29-32].

Vegetation architecture of the habitat also affect the diversity of species of spiders [33, 34]. We observed that spiders of Oxyopidae family found in shallot lived only in weeded areas. The complexity of the habitat structure is known as an important factor influencing the population dynamics of the spi-

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der [34, 35]. Biere and Uetz [36] stated that the structure of the vegetation and the microclimatic conditions play an important role for the spiders to select their micro-habitats. Besides, plant characteristics and neighbouring habitats also influence the spider communities [37, 38]. This is likely to occur in areas of Langowan and Tompaso where the farmers plant diverse crops, while the times of soil treatment, planting, watering, and harvesting are different that effect on migration of the spider community from one habitat to another.

Spider guild composition of the four habitat types of agricultural crops is shown in Fig. 2.2. There were seven guilds of spiders found in the four types of habitat, except that ambusher spider guild was not found in shallot. The seven spider guilds were orb-weavers, ground runners, space web builders, stalkers, wandering sheet weavers, foliage runners, and ambushers.

All habitats were dominated by the orb-weavers, then by the ground runners, and the space web builders. In the kidney bean plants the orb-weaver reached 43% of the samples collected, tomato 42%, maize 40%, and shallot 37%. The similar applied to other guilds with percentages varied between habitat types, as well as within the habitat type itself (Fig. 2.2). The structure of each habitat type describes the spider guild composition.

In general, the structure of spider guild is influenced by the host plant, the diversity, the microenvironment, and the level of disturbance [25, 39, 40]. Complexity of the crop structure determines the composition of spider guild, and indirectly affect the level of herbivore damage [39]. The complexity of the structure of agricultural crops will support resources and encourage more diversity of groups (assemblages) of spider species. In addition, simple plant structures such as shallot cannot increase the abundance and richness of the spider community, that causes low diversity of spiders.

4 Conclusion

The total collected sample of spider comprised 648 individuals consisting of 72 species, 36 genera, and 11 families. We collected from tomato habitat a total of 202 individuals from 51 species, 32 genera, and 11 families; from kidney bean habitat a total of 196 individuals, 45 species, 28 genera, and 11 families; from maize habitat a total of 140 individuals, 38 species, 25 genera, and 10 families; and from shallot habitat a total of 110 individuals, 29 species, 18 genera and 10 families.

There was a significant effect of four different habitat types of agricultural crops on the spider species diversity and richness, but there was no effect on the species distribution evenness. The highest species diversity was found in tomato habitat (3.33 ± 0.09), followed by kidney bean (3.20 ± 0.05), maize (2.96 ± 0.06), and shallot (2.72 ± 0.03). The highest species richness was found in tomato habitat (8.13 ± 0.31), followed by kidney bean (7.56 ± 0.28), maize (5.99 ± 0.32) and shallot (4.89 ± 0.07).

There were seven guilds of spiders found in four types of habitat. The ambushers guild was not found in the shallot habitat. All habitats were highly dominated by the orb-weavers, then the ground runners, and the space web builders.

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