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THE INFLUENCE OF DISTANCE BETWEEN OIL PALM PLANTATIONS AND FOREST ECOSYSTEMS ON SPIDER DIVERSITY

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***Abstract**. Forest conversion to oil palm plantations forms a unique agroecosystem. Forests known as a source of biodiversity are bordered by oil palm plantations with low diversity. The location of the oil palm plantation, which is directly adjacent to the forest, is thought to affect the diversity of spiders found in the agroecosystem. This study aimed to determine the effect of the distance between oil palm plantations and forests on spider diversity. The research was conducted at oil palm production centers in West Sumatra Province, Indonesia, namely Dharmasraya Regency, Pulau Punjung District, Nagari Gunung Selasih, and Sungai Kambut. In oil palm plantations, 10 sample plots (1 m x 1m) were determined along the transect line, 1 km from the forest's edge. Spiders were collected using the pitfall trap, knockdown, and hand collection methods. The spider diversity was analyzed by applying the diversity and evenness index by Shannon-Wiener. The results showed that the distance of the oil palm plantation from the forest affected the diversity of spiders. The closer the oil palm plantation is to the forest, the higher the diversity of spiders. The results of this study can be one of the considerations for oil palm business actors to maintain forests as conservation areas for organisms that provide various ecosystem services, including spiders as predators of oil palm pests.*
***Keywords:** abundance; diversity; ecosystem; natural enemies*

1. Introduction

Spiders are the largest predators within a terrestrial ecosystem. They possess several advantageous characteristics that are absent in other predators. According to Mashavakure *et al.* (2019), spiders belong to generalist predators and are more efficient in controlling pests than other specialist predators. Most spiders preys include order insect of Diptera, Colembolla, Coleoptera, Orthoptera, Lepidoptera, Hemiptera, Trysanoptera, Hymenoptera, and certain groups of spiders and other arthropods, even Nyffeler & Birkhofer (2017) estimated 400–800 million tons of prey are annually killed by the global spider community. Spiders are active predators in the daytime and nighttime with high mobility, enabling them to hunt either diurnal or nocturnal insect prey.

Spiders can adapt quickly to changing habitats and the availability of prey. As a result, if they live in a suitable environment and have abundant prey, spiders grow fast; hence their population increases drastically. Potapov *et al.* (2020) report that spiders spread vastly and live in hollows in any kind of habitat such as primary forest, secondary forest, grasslands (Milano *et al.*, 2021), industrial forest (Lamont *et al.*, 2017), agricultural land (Salman *et al.*, 2019), plantation

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(Shabnam *et al*., 2021), orchard (Lefebvre *et al*., 2016), food cropland (Pompozzi *et al*., 2021), rice-field area (Karenina *et al*., 2019) and even residential area (Jasmi *et al*., 2021). Spiders can move from one habitat to another if disturbed (Aguilera *et al*., 2019).

Spider habitat at risk of disturbance is forest even though the ecosystem offers a high diversity. The expansion of oil palm plantations sets an example of such a disturbance because most oil palm plantations are derived from forest conversion. Vijay *et al*. (2016) report that 45% of oil palm plantations in Southeast Asia and 30% in several countries of South America were obtained by conversing forests for such kind of agricultural purposes. Pirker *et al*. (2016) add that the expansion of oil palm plantations at the expense of tropical forests mainly takes place in Malaysia and Indonesia. Nearly 50% of oil palm plantations in both countries were converted from the forest (Vijay *et al*., 2016). Spiders can reflect the artificial changing in tropical structure within the ecosystem (Hamřík & Košulič, 2021). In line with this, Potapov *et al*. (2020) report that the population and diversity of the spider community are closely related to the complex structure of environments. It is evidenced by the study conducted by Liu *et al*. (2016) which report that manipulations of forest litter significantly affect spiders, especially web-building spiders.

Oil palm plantations are categorized as agro-ecosystems resulting from human manipulation and have been suspected to be the main cause of biodiversity loss, including spiders. Such is a reasonable assumption considering that several oil palm cultivation activities directly harm the habitats of various organisms, including land preparation using a slash-and-burn method or the use of various heavy equipment, monoculture cropping patterns, and cultivation processes massively applying various types of agrochemicals. Applying quick starter varieties encourages farmers to carry out intensive fertilization to produce more quickly. Pesticides are used as the main solution to prevent production from being reduced due to pest and disease attacks without considering other control methods. In general, most of these activities are intensified during the immature plant phase (IPP) but are decreased during the mature plant phase (MPP).

Compared to other agricultural ecosystems, the frequency of disturbance of spider habitat caused by oil palm cultivation is considered low. It relates to the fact that oil palm cultivation takes a relatively long time, that is, 27 to 30 years. In addition, the location of several plantations bordering the forest has been held responsible for spider diversity. It is not surprising given that the high diversity of spiders resides in forest ecosystems. For instance, Benítez-Malvido *et al*. (2020) collected a total of 110 spiders, of which 44 individuals from 29 species were found in forests. do Prado and Baptista (2021) found 457 species/morphoespecies in 47 families of spiders in the Atlantic forest area in Rio de Janeiro state, Brazil. In India, as reported by Chetia & Kalita (2012), 95 species of spiders live in the forests of Assam (these species are out of the 1520 species of spiders found in India (Sebestian & Peters, 2009). The location of oil palm plantations adjacent to the forest can be optimized because of this ecosystem's high diversity of spiders. It is assumed that the oil palm plantations bordering the forest enable high spider diversity and, as moving further from the forest, the diversity will decrease. The reduction is likely because the spiders move from the forest, which is usually considered the source of diversity, to oil palm plantations. This study aims to analyze the impact of the distance between oil palm plantations and forest ecosystems on spider diversity.

2. Methods

2.1. Study site and plot sampling

The research was conducted in the oil palm plantations bordering the secondary forest in Nagari Gunung Selasih and Sungai Kambut, Pulau Punjung Sub-district, Dharmasraya Regency, in the Province of West Sumatra. In both sites, the age of oil palms ranges from 15 to 17 years old. The study area is located at an altitude of 118 m to 300 m above sea level, with light intensity at 558.36 lux, temperature at 34.01°C, and humidity at 66%. At each location, sampled plots were randomly picked on a line transect (Rodrigues *et al*. 2015). The length of the transect line in the oil palm plantation ecosystem is 1 km. Along this line, ten sampled plots were marked for every 100 m apart. In the forest area, one sampled plot, whose size is 2 m x 2 m, was established with at a distance of 100 m from the forest edge.

2.2. Spider collection

Spiders were collected by using three methods, namely, pitfall traps (Shochat & Stefanov 2004), knockdown (Sorensen 2004), and hand-collecting (Sorensen 2004). A pitfall trap is a trap used to collect spiders on the ground. The trap was made from plastic glass with a diameter of 8 cm and a height of 11.5 cm, which was then planted on the ground with the surface position parallel to the ground surface. The glass was filled with 50 ml of water mixed with detergent or equal to one-third of the volume of the glass before its installation for 24 hours (Shochat & Stefanov 2004). The knockdown method was carried out by spraying an insecticide with the active ingredient cypermethrin 250 g/l onto oil palm plants and weeds in the sampled plots. A hand sprayer with a volume of 15 l and with a concentration of 2 ml/l was used for the spraying. The gauze was then spread under the sprayed oil palm plantations or in the sample plots. In this way, the gauze could catch spiders dying and falling from the tree after spraying (Argañaraz *et al*. 2017). Some species of dead web-building spiders did not fall to the ground but hung with their webs on the canopy. When this occurred, the sampled plants were shaken so that they fell on the cloth. The hand-collecting involved using bare hands or with the help of a brush. Forms of such direct collection include subduing branches and small trees, and filtering leaves, humus, and topsoil (Potapov *et* *al*., 2020). The hand collection was also done by peeling the bark and dead trees, piles of wood and stumps, and leftovers from land clearing (Cardoso *et al*. 2011).

2.3 Spider identification

The spider identification was carried out in two stages. In the first stage, the spiders were classified based on the similarities of their morphological characteristics through macroscopic observation. In the second stage, the identification involved microscopic observation by using binocular microscopes in the laboratory. The majority of spiders collected have reached the imago stadium for ease of identification. The spiders were identified meticulously at the species level following the literature by Gutierrez *et al.* (2019); Stenchly (2011); Maddison (2015); Prószyński (2016); Metzner (2018); Rollard & Wesolowska (2002); Bee *et al*. (2017), and Whyte & Anderson (2017).

2.4 Data analysis

The spider diversity was analyzed by applying the diversity and evenness index by Shannon-Wiener. To figure out how the distance between the oil palm plantation and the forest affects spider diversity, regression analyses were applied. The data were analyzed with the application of Primer Version 5 for Windows.

3. Results and Discussion

3.1. Spiders species and family in the oil palm plantations based on distance from the forest

Spiders were collected in the oil palm plantations bordering the forest as many as 68 species, 15 families, and 414 individuals (Table 2). The spider species with the highest abundance are *Argiope* sp., *Oxyopes javanus*., *Leucage* sp., *Misumenops* sp., and *Pardosa* sp (Table 1). It resonates with Motta and Levi (2009), who reported that there are 76 spider species of the genus Argiope and most of them are widespread in the tropics. Das *et al*. (2018) reported the high abundance of *Argiope* sp. in several types of forest habitats or fragmented habitats. Several factors at work regarding this abundance are related to their high adaptability, wide prey range, and availability of natural vegetation for web-building. In addition, *Argiope* sp. is synanthropic (having close contact with humans) and, as a result, they are not disturbed by the human activities in the oil palm cultivation. *Argiope* sp. are different from *Oxyopes javanus*. Although the latter shows high abundance, this is solely due to the prey availability in the area they live. *Oxyopes javanus* is a polyphagous predator that preys on approximately nine species of arthropods, with the main prey being insects from the Order of Diptera, Hymenoptera, Heteroptera, Orthoptera, and Lepidoptera (Huseynov, 2007). According to our study, most oil palm pests belong to the Order of Lepidoptera, which is suspected to be easy prey for *Oxyopes javanus*.

Table 1. Number of individuals of spider species in the oil palm plantations based on distance from the forest

Species	Distance of oil palm plantations from the forest (m)											Number of individuals
	0	100	200	300	400	500	600	700	800	900	1000	
Anepsion sp.	0	0	1	1	0	0	0	0	0	1	0	3
Argiope sp.	5	1	2	5	4	6	5	5	6	4	1	44
Deliochus sp.	0	2	0	0	0	0	0	0	0	1	0	3
Gasteracantha formicata	0	0	0	0	0	2	1	0	1	0	0	4
Gea sp.	2	0	0	0	0	0	0	0	0	0	0	2
Neoscona sp.	0	0	3	1	1	1	0	0	1	0	0	7
Nephila maculata	1	0	0	0	0	0	0	0	0	0	0	1
Clubiona sp.	3	2	2	1	2	2	0	3	0	2	2	19
Metidia sp.	0	0	0	0	1	0	0	0	0	0	0	1
Dyctina gramic	5	0	0	0	0	0	0	0	0	0	0	5
Oreo sp.	0	0	1	0	0	0	0	0	1	0	0	2
Hersilia sundaica	1	0	0	0	0	0	0	0	0	0	0	1
Zelotes latreillei	1	0	0	0	0	0	0	0	0	0	0	1
Hipposa sp.	1	1	0	0	1	0	0	0	1	0	0	4
Pardosa sp.	4	1	0	1	6	1	3	0	0	2	3	21
Pirata sp.	1	1	1	2	0	2	1	2	0	0	4	14
Schizocosa sp.	1	1	4	0	1	3	4	2	4	0	1	21
Oxyopes Javanus	3	2	5	3	1	3	3	6	5	5	2	38
Oxyopes sp.	0	0	1	2	2	1	1	1	0	0	0	8
Carrhotus sp.	1	1	0	0	0	0	0	0	0	0	0	2
Cosmophasis estrellaensis	0	0	0	0	0	0	0	0	0	1	0	1
Cosmophasis sp.	1	1	1	0	1	0	1	0	1	0	0	6
Cosmophasis trioipina	0	1	0	0	0	0	0	0	0	0	0	1
Epeus edwardsi	0	0	1	0	0	0	0	0	0	0	0	1
Hormochirus brachiatus	3	1	0	1	0	0	2	0	0	0	0	7
Ligura sp.	0	0	1	0	0	0	0	0	0	0	0	1
Phintella sp.	0	2	1	1	0	1	0	1	2	0	0	8
Phintella versicolor	0	0	0	0	0	0	0	1	0	0	0	1
Phintella vitteta	0	0	1	0	0	0	0	0	0	0	0	1
Plexippus calcuttaensis	0	1	0	0	0	0	1	0	0	0	0	2
Plexippus sp.	0	0	0	1	0	0	0	1	1	1	1	5
Rumburuka laxus	0	0	0	0	0	0	1	0	0	0	0	1
Rumburuka sp.	0	0	0	0	0	0	0	0	0	0	1	1
Salticus firgatus	0	2	1	0	0	0	2	5	3	2	1	16
Sidusa gratiosa	0	0	0	0	0	0	0	0	0	1	0	1
Talavera thorelli	0	2	0	0	1	0	0	0	0	0	0	3
Tanzania meridionalis	0	0	1	2	0	0	0	0	0	0	0	3
Thiania bhamoensis	0	0	0	1	0	0	0	0	0	0	0	1
Thiania gazellae	0	1	0	1	0	2	1	0	0	0	0	5
Thiania latibela	0	0	0	1	1	0	0	0	0	0	0	2
Thorelliola ensifera	0	2	2	1	0	0	0	1	0	2	0	8
Thorelliola joannae	0	1	1	0	1	0	0	0	0	0	0	3
Thorelliola pallidula	1	3	2	0	0	1	0	2	3	0	0	12
Thorelliola zabkai	0	1	0	0	0	1	1	0	0	0	0	3

Table 2. Number of individual spider species in oil palm plantations based on distance from forest (continued)

Species	Distance of oil palm plantations from the forest (m)											Number of individuals
	0	100	200	300	400	500	600	700	800	900	1000	
Thyenula armata	1	0	0	0	0	0	0	0	0	1	0	2
Thyenula wesolowskae	0	0	0	0	0	0	0	0	0	2	0	2
Tisaniba mulu	0	1	0	2	0	0	0	1	0	0	0	4
Truncattus flavus	0	0	0	0	1	1	0	1	0	1	0	4
Tylogonus auricapillus	0	0	0	0	0	0	1	0	0	0	0	1
Dictis striatipes	0	0	1	2	0	0	1	0	0	1	0	5
Scytodes pallidus	1	0	0	0	0	0	0	0	0	0	0	1
Scytodes tardigiade	0	0	0	0	0	0	0	0	0	1	2	3
Scytodes thoracica	2	0	1	0	0	1	0	0	0	0	0	4
Heteropoda jugulans	6	6	1	1	0	1	1	1	0	0	1	18
Seramba sp.	0	0	0	0	0	1	0	0	0	0	0	1
Leucage sp.	7	3	1	3	0	3	2	1	2	3	1	26
Pachygnatha	1	0	0	0	0	0	0	0	0	0	0	1
Enoplognatha ovata	2	0	0	0	0	0	1	0	0	0	0	3
Camericus sp.	0	0	0	1	0	0	0	0	0	0	0	1
Misumenops sp.	0	3	5	3	3	2	1	2	1	5	0	25
Misumenops vatia	0	0	1	0	0	0	0	0	0	0	0	1
Strophinae sp.	0	0	0	0	0	0	0	0	0	1	0	1
Synema globosum clarum	0	0	0	1	0	0	0	0	0	0	0	1
Tharpyna diademata	0	0	0	1	0	0	0	0	0	0	0	1
Thomisius sp.	0	0	0	0	1	0	0	0	0	0	0	1
Philoponella sp.	0	0	1	2	0	0	0	0	1	0	0	4
Uloborus lugubris	1	0	0	0	0	0	0	0	1	0	1	3
Melinella sp.	3	0	0	1	0	0	1	1	1	0	0	7
Total	58	43	43	42	28	35	35	37	35	37	21	414

The families with the highest number of species are Salticidae (Table 3). The Salticidae Family alone consists of 29 species. This number is considerably high hence striking compared to other families (Table 3). Salticidae is the Family with the highest number of species of the spider class. According to the Platnick (2009), Salticidae consists of 6,108 species and 636 genera. Most of these species spread in the tropical region, especially in Africa and Asia. In the oil palm plantations bordering the forest, 29 species of spiders from the Salticidae family are identified. The Family of Salticidae are terrestrial and are well-known as jumping spiders. Such an ability is supported by the remarkable and prominent characteristic of the Salticidae spider: a well-developed visual acuity characterized by large tubular eyes (Hill & Richman, 2009). The litter in forest ecosystems and oil palm plantations also accounts for the abundance of Salticidae. The remaining harvested stems and pruning are arranged on the gate and left to rot in the oil palm plantations. As a result, the litter has piled up quite high, given that the oil palm plants at the study site have reached 17 years of age. Marshall & Rypstra (2015) argue that the thicker the litter, the more humid the habitat. Besides, the piled-up litter can be a spot for prey to stay (prey availability) and for spiders to hide and avoid extreme temperatures. Argañaraz *et al*. (2017) agree with this and report that the species belonging to the Salticidae Family demonstrate a very close relationship with microhabitat, plant diversity, and prey.

Furthermore, Araneidae is the third-largest family in species number in the spider class. This Family of Araneidae includes Ecribellates, Entelegyne, three-claw spiders, and other spiders with eight eyes in two rows. In the oil palm plantations understudy, the diversity of Araneidae diversity is connected to the availability of habitat for building webs as the spiders belonging to this Family are known as web-builders. The high diversity of Araneidae in the forest is supported by the availability of trees of various heights for such web-building. In contrast, trees of such kind have been uprooted for land-clearing purposes in the oil palm plantations. This leaves the spiders of this Araneidae Family with no choice other than to make the oil palm trees an alternative habitat for them as the structure of the oil palm enables them to build webs. The oil palm trunks can reach a maximum height of 15 m with 48 to 56 fronds with a length of up to 4 m, depending on the variety. The overlapping palm fronds in a plantation serve as links or corridors for spiders to spread everywhere. Put differently, these fronds enable the spiders to move from one habitat to another.

Table 3. Number of individuals of every spider Family in the oil palm plantations based on distance from the forest

Famili	Distance of oil palm plantations from the forest (m)											Number of individuals
	0	100	200	300	400	500	600	700	800	900	1000	
Araneidae	8	3	6	7	5	9	6	5	8	6	1	64
Clubionidae	3	2	2	1	3	2	0	3	0	2	2	20
Dictynidae	5	0	0	0	0	0	0	0	0	0	0	5
Gallieniellidae	0	0	1	0	0	0	0	0	1	0	0	2
Gnaphosidae	2	0	0	0	0	0	0	0	0	0	0	2
Lycosidae	7	4	5	3	8	6	8	4	5	2	8	60
Oxyopidae	3	2	6	5	3	4	4	7	5	5	2	46
Salticidae	7	20	12	11	5	6	10	13	10	11	3	108
Scytodidae	3	0	2	2	0	1	1	0	0	2	2	13
Sparassidae	6	6	1	1	0	2	1	1	0	0	1	19
Tetragnathidae	8	3	1	3	0	3	2	1	2	3	1	27
Theridiidae	2	0	0	0	0	0	1	0	0	0	0	3
Thomisidae	0	3	6	6	4	2	1	2	1	6	0	31
Uloboridae	1	0	1	2	0	0	0	0	2	0	1	7
Zodariidae	3	0	0	1	0	0	1	1	1	0	0	7
Total	58	43	43	42	28	35	35	37	35	37	21	414

The composition of spiders based on the distance of the oil palm plantation from the forest shows that the highest number of spider families and individuals was found at a distance of 0 m, namely 13 families and 58 individuals. The number of individuals declines when the collection moves further away from the forest, although this pattern only demonstrates consistency at a distance of 0-400 m. The number of individuals declines considerably at a distance of 1000 m from the forest. Interestingly, this study found that the highest number of spider species was spotted at a distance of 200 and 300 m from the forest as many as 26 species (Table 1).

The oil palm plantations bordering the forest have a high number of individuals and families of spiders (Table 3). In this site, Araneidae is a spider family that has high species richness. At a distance of 0 m from the forest, Araneidae was more abundant than those of other families. The finding is in line with the previous study reported by Baldissera *et al.* (2008). They argue that the abundance of Araneidae is higher inside the forest rather than at the forest edge. Our finding is related to the type of forest where the sample was taken, which is categorized as a secondary forest. In a secondary forest, the forest edge is not heavily populated with dense trees, and, in addition, these trees can only grow as tall as 4 to 7 meters. According to Foelix (2011), the place for web-building requires a specific microclimate and adequate space. Regarding this, dense trees in the forest will make it difficult for spiders to build webs because, as Levi (2002) argues, Araneidae is known as ball web-building spiders. Because of this, they require a large space for web-building. Furthermore, several environmental factors also affect the spider communities, especially wind, and temperature. Strong wind in the forest can damage the spider's web (de souza & Martins, 2004), and higher temperatures at the forest edge affect the abundance of Araneidae in the oil palm plantations bordering the forest. High temperature is also responsible for the diversity of Araneidae in certain areas in that the higher the temperature of an area, the more diverse the spiders living there. Rodrigues *et al.* (2015) support this and report that the temporal distribution of Araneidae shows a peak during summer. However, they also point out that not all spider families respond to such a situation in the same way.

3.2. Spider diversity in oil palm plantations bordering the forest

The results of spider diversity in this study do not show consistency with the number of individuals and families. Previous studies have reported that the number of individuals and families declines if the oil palm plantations are set further apart from the forest, ranging from 0 to 400 m from the forest. On the other hand, the highest diversity index of spiders is found at a distance of 300 m from the forest, and the lowest is at a distance of 1,000 m. This finding leads to the conclusion that the distance factor is in proportion to the spider diversity in that the further away from the forest, the lower the spider diversity. Furthermore, the highest evenness index occurs at a distance of 300 m from the forest (Table 4). However, as a whole, the evenness index value for certain distances from the forest is >0.9. This suggests that the spider species living in the oil palm plantations are evenly distributed. In other words, no spider species has domination over the other species.

Table 4. Spider diversity index in oil palm plantations bordering the forest

Indeks	Distance of oil palm plantations from the forest (m)										
	0	100	200	300	400	500	600	700	800	900	1000
Diversity	2.97	3.06	3.05	3.11	2.53	2.77	2.86	2.65	2.59	2.75	2.43
Evenness	0.94	0.94	0.94	0.95	0.9	0.92	0.93	0.91	0.91	0.92	0.9
Number of individuals	58	43	43	42	28	35	35	37	35	37	21
Species richness	25	25	26	26	16	19	21	18	17	19	13

The spider diversity measured at various distances from the forest appears to be inconsistent. Spider diversity is high at 0 m but then fell to 300 m. However, it increases again at a distance of 500 m to 900 m, although the number is not as high as that of 0-300 m. This is associated with the fact that the spiders in oil palm plantations originate from different sources. While the spiders are suspected to originate from the forest at a distance of 0-300 m, at a distance of 500-900 m, the spiders are believed to have formed colonies that still survive after land clearing. The fact that the oil palm plantation area and the forest are relatively close to each other likely allows the spiders from each area to move around the respective habitat. Some similarities between the forest ecosystems and oil palm plantations can also be a factor in spider diversity. These similarities include microhabitat conditions such as temperature, humidity, wind, and light intensity. Plenty of forest litter is also found in oil palm plantations. Although not as dense as the forest, the oil palm plantations are also overgrown with various low vegetation. Oil palm cultivation in plantations located around the forest edge is rarely affected by agronomic activities, especially by weed control activities. The oil palms also provide a variety of prey for predatory spiders, which, at the same time, are the oil palm pests. This condition mostly occurs in the sampled plot of 400 m distance from the forest.

3.3. The influence of forest distance on spider diversity and abundance

The results of the regression analysis show that spider diversity has a positive relationship with the distance of oil palm plantations from forests (R^2 =0,59) (Figure 1) while evenness had a positive relationship (R^2 = 0,53) (Figure 2). If the regression analysis value is 0.59 and 0,53, it means there is a positive relationship between the independent variable and the dependent variable, but the relationship has not been said to be strong or close. The regression analysis value ranges from -1 to 1, where a value of 1 indicates a strong and positive relationship, while a value of -1 indicates a strong and negative relationship between the independent and dependent variables. A value of 0 indicates that there is no linear relationship between the two variables. Therefore, the value of 0.59 and 0,53 indicates a positive relationship between the two variables, but further testing is still needed to ensure the strength of the relationship.

Differences in the number of individuals and species richness at several sampled plots distancing from the forest affect spider diversity. This is evident by the high spider diversity index at a distance of 300 m from the forest, whereas the highest number of individuals was found at a distance of 0 and 100 m from the forest. At a distance of 300 m, 26 species of spiders were found, and this number turned out to be the highest from the other plots under observation. Overall, it can be concluded that the further away the spiders live from the forest, the less diversity they have. This confirms the study reported by Baldissera *et al.* (2008). They argue that the geographical location of the forest with Araucaria plantations affects spider diversity. This is in contrast with the evenness index, which is nearly similar at any distance from the forest, reaching as high as > 0.9, meaning that the distribution pattern of spiders at several distances from the forest is evenly distributed. Regarding this, (Cornell & Lawton, 2012) argue that the distribution of organisms can be determined by their capacity for dispersion and colonization. On the other hand, ambiguous interactions on a local spatial scale can influence the number of organisms in a population. Although manipulations taking place in forests can potentially affect the spider population negatively, in the long run, such disturbances can also promote spider diversity. This is because humans' effects of habitat modification are highly dependent on the level and frequency of disturbances.

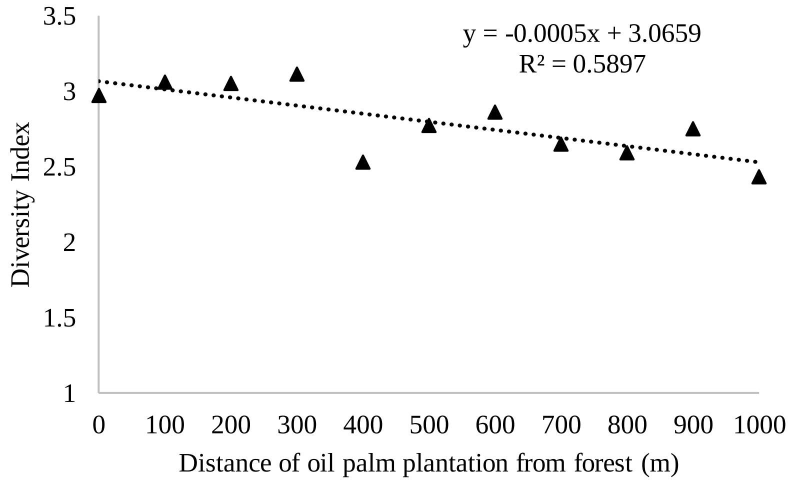

Figure 1. The relationship between the distance of oil palm plantations from the forest on the diversity of spider species.

It is interesting to notice that *Argiope* sp., *Heteropod jugulans*, *Leucage* sp. are spiders that are abundant at a distance of 0 m from the forest, but then drastically fall at a distance of 100 m and are completely absent at the distance of 200-400 m from the forest. *Argiope* sp, though, is the only spider species that spread evenly at several distances from the forest. This is interesting considering that this species is classified as a web-builder which requires sufficient vegetation. Also, *Argiope* sp can build webs on various plants with different heights, even on weeds with a height of 1 m. In contrast to Salticidae, *Argiope* sp has low diversity in lower vegetation because they live and build webs on plants with a height of more than 2 m (Argañaraz *et al*., 2017). In the oil palm plantations, the predominant weeds are 2 m in height, and the lower vegetation grows evenly. The spider abundance is in proportion to the diversity of lower vegetation because the latter provides a place for web-building, affects prey availability, and protects the spiders from predatory birds (Schmidt *et al*., 2005). The oil palms with long overlapping fronds can serve as a vehicle for Argiope sp. to move from forest to various niches in the oil palm plantations.

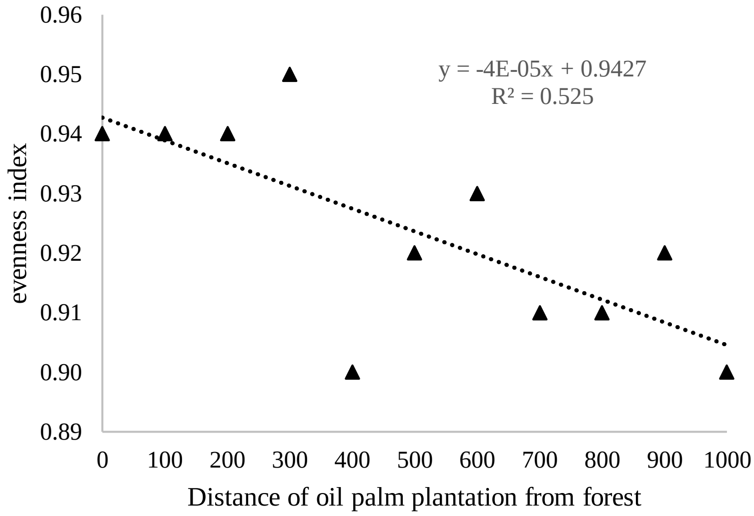

Figure 2. The relationship between the distance of oil palm plantations from the forest on the evenness of spider species.

4. Conclusions

The spider diversity in the oil palm plantations under study differs from one sampled plot to another, depending on their distance from the forest. The proximity of the oil palm plantations to the forest gives rise to spider diversity. This is particularly the case in the sampled plot situated at 100 m to 300 m from the forest. The spider evenness index is also higher in the oil palm plantations bordering the forest, particularly in the sampled plot at the distance of 100 m to 300 m.

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