Journal of Applied Agricultural Science and Technology
4 (2): 101-117 (2020)
E-ISSN: 2621-2528
ISSN: 2621-4709

DIVERSITY OF PREDATORY ARTHROPODS IN SOYBEAN (*GLYCINE MAX* L) REFUGIA

Erise Anggraini*[,1,2], Roy Pardingotan[1], Siti Herlinda[1], Chandra Irsan[1], Muhammad Umar Harun[3]

[1]Department of Plant Pests and Diseases, Sriwijaya University, Palembang, Indonesia.
[2]Study Program of Sustainable Agriculture, Sriwijaya University, Palembang, Indonesia.
[3]Department of Agronomy, Sriwijaya University, Indonesia.

*Corresponding author
Email: erise.anggraini@unsri.ac.id

Abstract. *Many problems arise in the cultivation of crops; one of these problems is insect pests that can threaten crop production. Integrated pest management is an alternative technique for managing the balance of the agricultural environment. Habitat manipulation by increasing plant diversity with refugia is considered an alternative way to maintain natural enemy in an agro ecosystem. The use of soybean as a refugium in a crop field is still limited. Research was conducted to investigate the diversity of predatory arthropods in soybean as a refugium in a chilli pepper crop field at the Agro-technology Training Centre (ATC) at the University of Sriwijaya. In this study, four varieties of soybean (Dena 1, Detam 3 PRIDA, Deja 1, and Devon 1) were used as refugia. Three observation methods were carried out using nets, pitfall traps and visual observation for 7 weeks. The results show that arthropod diversity in soybean plants comprised 6 orders with 10 families and 19 species. Odontoponera denticulata (Hymenoptera) was the most predominant arthropod predator, observed in 73% of all soybean varieties. The number of canopy-dwelling arthropod predators was similar in the four soybean varieties.*
Keywords: *refugium; predatory arthropods; soybean.*

1. Introduction

For pest control, farmers in Indonesia generally use synthetic pesticides. The use of synthetic pesticides generates a fast response in terms of killing plant pests; however, the continuous use of synthetic pesticides threatens the future of crop protection because it can have negative impacts. According to Aktar *et al*. (2009), some of the hazards of pesticide use are direct impacts on humans, particularly production workers, formulators, sprayers, mixers, loaders, and agricultural workers. They are at high risk of being exposed to pesticides during manufacture and formulation. Also, pesticides leave residues on plant products; for example in a study performed in 1996, there were seven pesticides (acephate, chlopyriphos, chlopyriphos-methyl, methamidophos, iprodione, procymidone, and chlorothalonil) and two groups of pesticides (the benomyl group and maneb group, namely dithiocarbamates) found in apples, tomatoes, lettuce, strawberries, and grapes. Moreover, pesticides can contaminate soil, water, grass, and other vegetation and are common contaminants in soil, air, water, and non-target organisms in urban landscapes. Therefore, to reduce the negative impact of pesticides, an environmentally friendly alternative method of pest control is needed.

Received 12 April 2020; Received in revised form 27 August 2020; Accepted 27 August 2020
https://doi.org/10.32530/jaast.v4i2.165

Integrated pest management (IPM) is considered a solution to protect crop cultivation (Zadoks, 1993). IPM is an ecologically-based pest control strategy that relies heavily on natural mortality factors such as natural enemies and weather and seeks out control tactics that disrupt these factors as little as possible (Flint & Van den Bosch, 2012). There are six basic elements in IPM programmes; one of them is to monitor the numbers and state of ecosystem elements, e.g. resources, pests, and natural enemies (Flint & Van den Bosch, 2012). In recent years, the application of IPM has been widely adopted as an alternative strategy to control pest attack in crop cultivation. This crop protection strategy prioritises reduced dependence of synthetic pesticide application to reduce pest resistance and to maintain the sustainability of agro ecosystems (Indiati & Marwoto, 2017).

Habitat manipulation by increasing plant diversity is a principal IPM tactic, which focuses on conserving the presence of natural enemies in crop fields (Kumar *et al.*, 2013). Plant diversity leads to a higher abundance of natural enemy arthropods in an ecosystem (Ebeling *et al.*, 2014). Natural enemies are organisms that kill, decrease the reproductive potential, or reduce the numbers of another organism (Flint & Dreistadt, 1998). Predation, parasitism, and parasitoidism of pests by natural enemies play a key role and have occurred since the evolution of the first terrestrial ecosystems some 500 million years ago (Vacante & Bonsignore, 2017). In pest management, the presence of these natural enemies is essential in reducing pest attacks, although this may not completely suppress pests (Gonçalves & Pereira, 2012).

Arthropod predators (spiders and insect predators) are natural enemies commonly found in many agroecosystems. They are often the most abundant and diversified natural enemies, and contribute to the reduction of several pests (Pekár, 2013). Predators typically consume several prey species during their lives and can be predacious when immature, as adults, or during both phases of their lives (Strand & Obrycki, 1996). Predators are distributed broadly across approximately 20 insect orders (New, 1991). According to Capinera (2008), predatory insects widely recognised in pest management programs primarily are found in the orders Coleoptera, Diptera, Hemiptera, Hymenoptera, and Neuroptera. Other predatory arthropods include the Acari and Arachnida (spiders). There are at least 30,000 species of spiders found in agricultural systems that receive few pesticide applications (Capinera, 2008). Predatory arthropods are often less studied than parasitoids, although the number of predator species and individuals in agricultural ecosystems that are not treated with pesticides may be very large (Capinera, 2008). Therefore, we focused on the presence of predatory arthropods in this study.

The conservation of natural enemies requires a suitable refugium to increase predatory arthropod numbers around cultivated plants. Previous research reported the application of wild plants as a refugium, for instance *Zinnia* sp. (Desai *et al*. 2017) and *Tagetes erecta* (Ganai *et al.*, 2017). Hassan *et al*. (2016) also stated that wild vegetables are effective refugia to support the presence of natural enemies. More recent research reported by Karenina *et al*. (2019) showed that the highest species diversity of spiders and predatory insects was found on rice surrounded by refugia, i.e. rice surrounded by refugia flowers and vegetables provided the most appropriate habitat and niche for predatory arthropods. The use of vegetable refugia planted around the main rice crop seems very realistic, as apart from being able to harvest rice, farmers can also harvest vegetables. In previous research, refugia have often been vegetable plants, but the use of soybean as a refugium in a crop field is still limited. Therefore, in this study, we were interested in evaluating the predatory arthropods present in soybean plants used as a refugium for the main chilli plant crop.

2. Methods

2.1. Field conditions

This research was conducted in May-July 2019 with rain intensity of 50-100 mm (BMKG, 2019). Field cultivation was carried out using a tractor before applying 10 kg of manure in the soil in each replication. The field area was 36 x 15 m, divided into three plots of 12 x 15 meters with a 0.5 meter-wide trench as the replication. Soybean as the refugium was cultivated about two meters on each side of the field at the Agro-Techno Centre (ATC), Sriwijaya University, District of Indralaya, Province of South Sumatera, Indonesia. The soybean crop was planted two weeks earlier than the main crop, chilli pepper. Four certified soybean varieties, i.e. Dena 1 (shade resistant), Detam 3 PRIDA (drought resistant), Deja 1 (water resistant), and Devon 1 (high isoflavone content of 2,219.7 μg/g) were obtained from the Indonesian Legumes and Tuber Crops Research Institute. The selection of the soy varieties was based on the growth and development of soybeans suitable for planting in this area (unpublished data). The four types of soy surrounded the main crop (chilli pepper) with three replications (an illustration of the experiment plot is provided in the Appendix). The red chilli pepper planted was a hybrid variety with a total of 741 chilli plants. Three observation method were used for collecting data in the field: visual observation, insect net traps and pitfall traps. In each replication, there were five points for the pitfall traps and the insect net traps to collect samples. The number of obtained individuals were recorded and analysed.

2.2. Visual observations, pitfall trap and net applications

All observations were conducted from early planting until harvest. Visual observations were done every week at 6:00-7:00 am, during which the presence of insects in the plant canopy was captured by a camera. The application of the pitfall trap was carried out two weeks after planting. The installation of this trap was done in the evening and observed 24 hours after installation. The trap was made by digging a hole in the soil to a depth of 15 cm and 8 cm in diameter, and then placing a plastic container (mineral water bottle) into the ground parallel to the surface of the soil. The plastic container was filled with water mixed with 3 ml of 90% alcohol. Collected insects put were into vials filled with 90% alcohol. The collected insects were observed and identified under a microscope at the Entomology Laboratory of the Plant Pest and Disease Department, Agriculture Faculty, Sriwijaya University. The insect net used was 35 cm in diameter and 50 cm in length with a 100 cm-long pole. Swing nets used were to catch insects in the leaves or canopy. The net was swung with two double swings in each plot. Trapped insects were taken and placed in jars for identification at the Entomology Laboratory, Department of Plant Pest and Disease, Sriwijaya University.

2.3. Data analysis

The abundance of predatory arthropods species was used to analyse the structure of the arthropod community. The diversity measurement used the Shannon-Weiner species diversity index for analysis. The abundance data of predatory arthropods species were reported using descriptive analysis, the number of insects was analysed by analysis of variance (ANOVA). Significant differences in the data were analysed using a mean separation test (Tukey-HSD) at alpha 0.05.

The Shannon-Wiener Index (H') was calculated following Magurran (1988) by using the formula: $H' = -\sum (pi \times \ln(pi))$, where H' is the Shannon-Wiener index, ln is the natural logarithm, N is the number of all individuals, ni is the number of individuals in a species, and pi is the proportional number of individuals in a species ($pi = ni/N$). The dominance index was calculated by following Barger and Parker (1970) with the formula: $d = N_{max}/N$, where N_{max} is the number of individuals in the most abundant species, and N is the total number of individuals in the sample. The evenness index was calculated by the following formula: $E = H'/\ln S$, where H' is the Shannon-Wiener index and S is the number of species. The evenness index value ranges from 0 to 1; if the value is 0, it indicates that the evenness level of plant species in the community is very uneven, whereas if the value is close to 1, then almost all the species that exist have the same abundance (Magurran, 1988).

3. Results and Discussion

We identified 19 species total of arthropods in soybean plants used as a refugium. The observed insects were classified into 6 orders of 10 families, as described in Table 1. We also compared the abundance of the arthropod community using three observation methods, i.e. visual observations, nets, and pitfall traps. Arthropod diversity was calculated using the Shannon-Weiner diversity index, shown in Table 2.

Table 1. Insect species found in soybean plants at the ATC of Sriwijaya University

Order	Family	Species
Araneae	Oxyopidae	*Oxyopes javanus*
		Oxyopes lineatipes
		Oxyopes birmanicus
		Oxypes sp.
	Lycosidae	*Pardosa sumatrana*
		Pardosa milvina
		Pardosa monticola
		Pardosa nemoralis
		Pardosa sp.
		Schizocosa malitiosa
Coleoptera	Coccinelidae	*Cocinella repanda*
		Mycraspis sp
	Staphylinidae	*Paederus fuscipes*
	Carabidae	*Cicindela sp.*
Diptera	Asilidae	*Promachus vertebratus*
Odonata	Coenagrionidae	*Ischnura heterosticta*
	Gomphidae	*Arigomphus villosipes*
Mantodea	Mantidae	*Mantis religiosa*
Hymenoptera	Formicidae	*Odontoponera denticulata*

The dominance index was used to indicate the distribution of the dominant types of arthropods in the crop fields. The dominance index (D) is inversely related to the evenness index (E), i.e. the higher the dominance index, the smaller the evenness index. The results show that the highest dominance index obtained was in four soy varieties using pitfall traps; in contrast, the evenness index was smaller in the data on species obtained by the pitfall trap compared to species obtained by the net trap and visual observations (Table 2). This indicates that predatory ground arthropods were the dominant species. Meanwhile, there were no dominant predatory arthropods species in the canopy. Based on the Shannon-Wiener diversity index, predatory arthropods trapped using pitfall traps were more diverse for each soy variety than predatory arthropods caught by net traps and visual observations. This means that predatory ground arthropods were more diverse.

Based on the statistical analysis, the number of all found species by using the net method was not significantly different (P-value 0.05) in each variety can be seen in Table 3. It indicated that the number of predatory arthropods in canopy habitat in four types of soybean was similar.

Identification of predatory arthropods in the experimental field at the ATC was also conducted to compare the richness of arthropods in four soybean varieties. Based on visual observations, there were 10 arthropod species including *Oxyopes javanus*, *Oxyopes lineatipes*, *Oxyopes sp.*, *Schizocosa malitiosa, Mycraspis sp., Paederus fuscipes, Promachus vertebratus, Ischnura heterosticta, Arigomphus villosipes,* and *Mantis religiosa* (Figure 1). We identified 10 species during observations with the net method (Figure 2), including three families Oxyopidae, two families Coccinelidae, and one family each of Staphylinidae, Asilidae, Coenagrionidae, Gomphidae, and Mantidae in four soybean varieties. Meanwhile, we identified ten species spiders, three species predatory insect from Ordo Coleoptera, and one ordo from Hymenoptera (Figure 3).

Table 2. Arthropod predator diversity index in soybean plants in the ATC experimental field at Sriwijaya University

Methods	Diversity index	Variety			
		Dena 1	Detam 3 PRIDA	Deja 1	Devon 1
Net	Number of individuals (individuals/3 nets)	21.00	14.00	14.00	15.00
	Diversity index (H')	1.87	1.77	1.67	1.31
	Dominant index (D)	0.29	0.36	0.43	0.40
	Evenness index (E)	0.90	0.91	0.86	0.94
Pitfall trap					
	Number of individuals (individuals/3 nets)	400.00	335.00	334.00	401.00
	Diversity index (H')	2.48	2.56	2.64	2.48
	Dominant index (D)	0.84	0.73	0.80	0.82
	Evenness index (E)	0.32	0.46	0.35	0.34
Visual					
	Number of individuals (individuals/3 nets)	15.00	29.00	21.00	13.00
	Diversity index (H')	1.62	1.99	1.66	1.88
	Dominant index (D)	0.33	0.28	0.48	0.31
	Evenness index (E)	0.90	0.91	0.80	0.91

Table 3. Mean number of predatory arthropods in four soybean varieties obtained using the net method in the experimental field

Species	Mean of population (individuals) in each varieties				F-value	P-value (0.05)
	Dena 1	Detam 3 PRIDA	Deja 1	Devon 1		
Oxyopes javanus	1.33	0.66	0.33	0	2.05	0.20
Oxyopes lineatipes	2	0.66	2	1	0.51	0.68
Oxyopes birmanicus	0.33	1.66	0.66	0	2.80	0.13
Cocinella repanda	0	0.66	0.66	2	1.76	0.25
Mycraspis sp.	1.33	0	0	1.33	2.06	0.20
Paederus fuscipes	0.66	0.33	0	0	2.20	0.18
Promachus vertebratus	0	0	1	0.66	1.00	0.45
Ischnura heterosticta	0.66	0.33	0.33	0	0.72	0.57
Arigomphus villosipes	0.33	0	0.33	0	0.57	0.65
Mantis religiosa	0.33	0.33	0	0	1.00	0.45

Visual observation and net traps were aimed at studying the presence of predatory arthropods in the plant canopy. There were differences in the number of insect species present in visual observation and net traps. Not all predatory arthropods become trapped in the net trap, and some predatory arthropods can quickly escape before becoming caught in the net. By both visual observations and net traps, the spiders found in this study were from family Oxyopidae. Oxyopids are not web builders but are rather diurnal cursorial hunters and are most commonly found amongst the stems of tall grasses and low shrubs (Dondale & Redner, 1990). They actively pursue their prey and seize by leaping (Cutler *et al*. 1977).

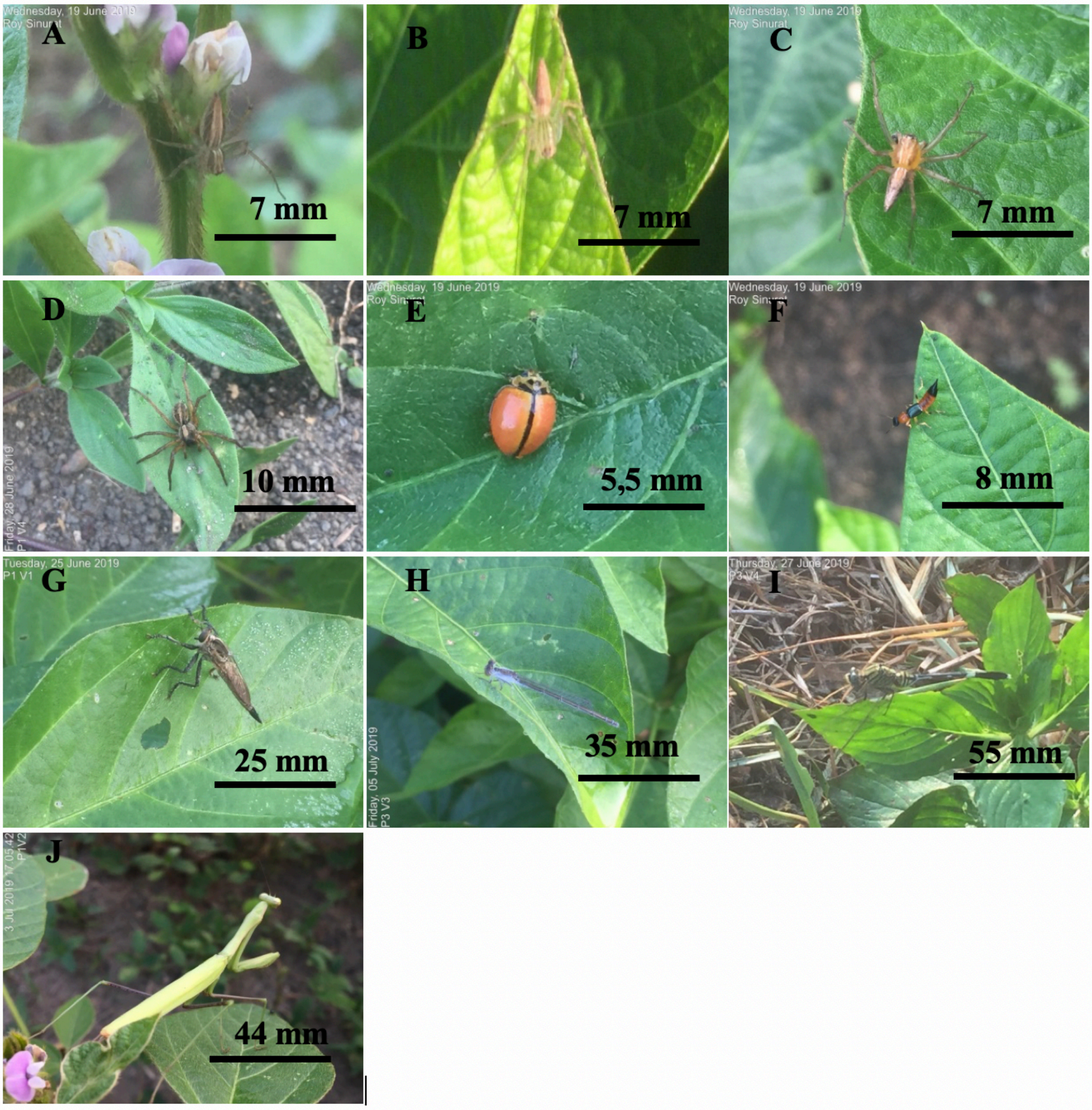


Figure 1. Predatory arthropods that were found by direct visual observation; A) *Oxyopes javanus*, B) *Oxyopes lineatipes*, C) *Oxyopes sp.*, D) *Schizocosa malitiosa,* E) *Mycraspis sp.,* F) *Paederus fuscipes, G*) *Promachus vertebratus,* H) *Ischnura heterosticta,* I) *Arigomphus villosipes,* J) *Mantis religiosa*

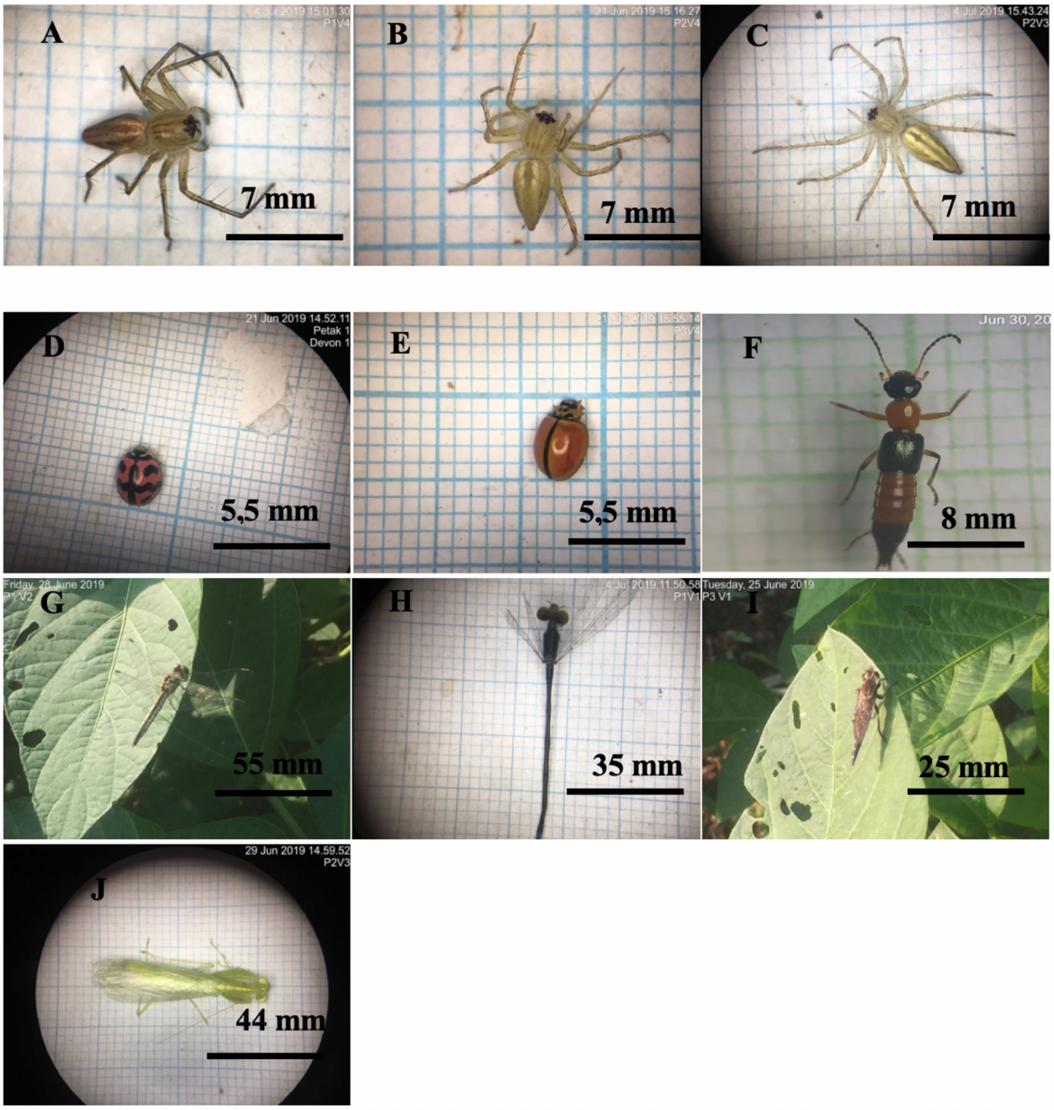


Figure 2. Predatory arthropods found in nets: A) *Oxyopes javanus*, B) *Oxyopes lineatipes*, C) *Oxyopes birmanicus,* D) *Cocinella repanda,* E) *Mycraspis* sp., F) *Paederus fuscipes,* G) *Arigomphus villosipes,* H) *Ischnura heterosticta,* I) *Promachus vertebratus,* J*) Mantis religiosa*

The identification of arthropods in four soybean varieties using the pitfall trap method is shown in Table 4. Based on the statistical analysis, only *Pardosa sumatrana* showed a significant difference between varieties (P-value 0.05). The highest total individual number of *P. sumatrana* was on the Devon 1 and Dena1 varieties (Tukey HSD at alpha 0.05).

The ground spider *Pardosa sumatrana* was found in high numbers on Devon 1. This is likely because the growth of the Devon variety soybean is denser and provides a suitable niche for *P. sumatrana* because the spider forms webbing to provide daytime shelter, not to capture prey. *P. sumatrana* plays an important role in the suppression of pest insects in fields and gardens (Biswas & Raychaudhuri, 2003). According to research by Hanumanthraya and Girish (2009), *P. sumatrana* Thorell is the most dominant spider species in both monocropping (36.45%) and multiple cropping systems (31.06%).

Table 4. Mean number of predatory arthropods in four soybean varieties using pitfall traps

Species	Mean of population (individuals) in each varieties				F-value	P-value (0.05)	Tukey HSD Test
	Dena 1	Detam 3 PRIDA	Deja 1	Devon 1			
Oxyopes sp.	0	0.66	1	0.66	0.67	0.59	-
Oxyopes lineatipes	0.33	0.66	0.66	0	1.00	0.45	-
Oxyopes javanus	1	2.66	0.66	1.66	1.33	0.34	-
Pardosa sumatrana	3^{b}	2^{ab}	0.66^{a}	4^{b}	9.12^{*}	0.01	2.41
Schizocosa malitiosa	3.66	6.33	6.66	2.66	2.15	0.19	-
Pardosa milvina	1.33	2	1	3	3.11	0.11	-
Pardosa monticola	5.33	8	4.33	3.66	1.66	0.27	-
Pardosa sp.	3.66	3.33	3.33	4.33	0.18	0.90	-
Pardosa nemoralis	2.33	2	2.33	2.66	0.06	0.97	-
Cocinella repanda	0	0.33	0.66	0.66	1.37	0.33	-
Mycraspis sp.	0	0	0.33	0	1.00	0.45	-
Cicindela sp.	1.33	2	0.33	0.33	2.00	0.21	-
Odontoponera denticulata	111.33	81.66	89.33	110	1.02	0.44	-

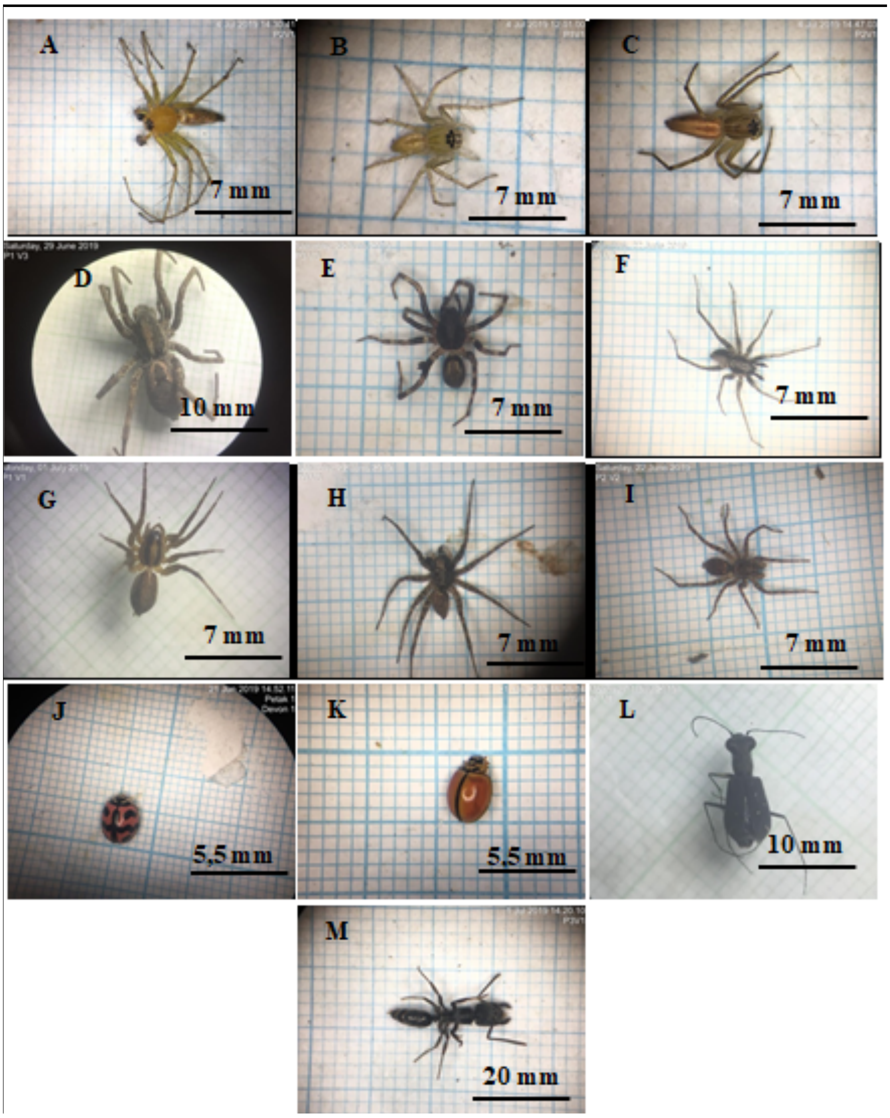


Figure 3. Predatory arthropods that found in pitfall traps: A) *Oxyopes sp.*, B) *Oxyopes lineatipes*, C) *Oxyopes javanus*, D) *Schizocosa malitiosa,* E) *Pardosa sumatrana,* F) *Pardosa milvina,* G) *Pardosa agricola,* H) *Pardosa monticola,* I) *Pardosa nemoralis,* J*) Cocinella repanda,* K) *Mycraspis sp.,* L) *Cicindela sp.,* M) *Odontoponera denticulata.*

The number of individual predatory arthropods in the four soybean varieties is shown in Table 5. Based on the data, the presence of *Odontoponera denticulata* was very high, reaching 1,177 individual in total on all soybean varieties. *Mantis religiosa* was the species with the lowest number of individuals in the experimental field, followed by *Oxyopes sp*., *Oxyopes birmanicus,* and *Paederus fuscipes* with fewer than 10 individuals.

Table 5. Total number of predatory arthropods found in soybean varieties in all traps

Species	Variety				Number of individuals
	Dena 1	Detam 3 PRIDA	Deja 1	Devon 1	
Oxyopes sp.	1	2	3	2	8
Oxyopes lineatipes	7	6	11	4	28
Oxyopes javanus	7	12	4	6	29
Oxyopes birmanicus	1	5	2	0	8
Pardosa sumatrana	9	6	2	12	29
Schizocosa malitiosa	11	20	20	9	60
Pardosa milvina	4	6	3	9	22
Pardosa monticola	16	24	13	11	64
Pardosa sp.	11	10	10	13	44
Pardosa nemoralis	7	6	7	8	28
Cocinella repanda	0	3	4	8	15
Mycraspis sp.	6	2	2	5	15
Cicindela sp.	4	6	1	1	12
Paederus fuscipes	2	5	1	0	8
Promachus vertebratus	4	10	10	5	29
Ischnura heterosticta	4	6	3	1	14
Arigomphus villosipes	5	4	3	4	16
Mantis religiosa	2	2	1	1	6
Odontoponera denticulata	334	245	268	330	1177
Total					1612

The classification of predatory arthropods into orders is shown in Table 6. The highest presence of total predatory arthropods was seed in the Dena and Devon 1 varieties, followed by Detam 3 PRIDA and Deja 1. This result indicates that the Dena and Devon 1 varieties are suitable to conserve the presence and abundance of natural arthropods during cultivation in this area. The most dominant order observed in all soybean varieties was Hymenoptera, of which 73% were in the family Formicidae (Figure 4). The Dena variety showed the highest number of Hymenoptera, followed by Devon, Deja, and Detam 3 PRIDA, respectively.

Table 6. Number of predatory arthropod species on soybean plants in each order

Order	Varieties			
	Dena 1	Detam 3 PRIDA	Deja1	Devon 1
Hymenoptera	334	245	268	330
Araneae	74	97	75	74
Coleoptera	12	16	8	14
Diptera	4	10	10	5
Odonata	9	10	6	5
Mantodea	2	2	1	1
Total species	435	380	368	429

Order Hymenoptera had the highest percentage, about 73%, because ants (*O. denticulata*) belong to this category and are dominant in organic and non-organic agriculture (Putra *et al*., 2017). Order Araneae placed second with 19.9%. The other orders, i.e. Coleoptera, Diptera, Odonata, and Mantodea, were only observed in small numbers.

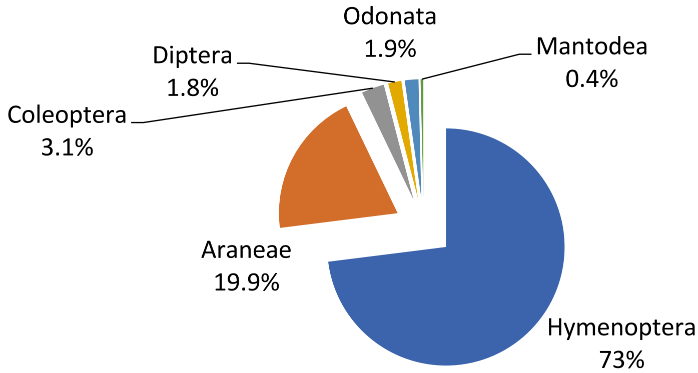


Figure 4. Percentage of predatory arthropods in each order.

The Detam 3 PRIDA variety showed the highest number of order Aranae, which consisted of *Pardosa monticola*. *Oxyopes birmanicus* was not found in the Devon variety. *Pardosa monticola* and *Schizocosa malitiosa* were the most numerous species found, whereas *Oxyopes birmanicus* and *Oxyopes sp.* were the rarest species found on all soybean varieties.

Predatory arthropods from the order Coleoptera were *Cocinella repanda*, *Paederus fuscipe, Mycraspis sp*., and *Cicindela sp. C. repanda* was most commonly found on the Devon 1 variety, while *Mycraspis sp.* was mostly found on Dena 1, and *Cicindela* sp. and *Paederus fuscipes* were mostly found on Detam 3 PRIDA.

Arthropod species from the order Diptera also recorded during visual observations. We found the same number of individual *Promachus vertebratus* species on the Detam 3 PRIDA and Deja 1 varieties. The fewest number of *Promachus vertebratus* was observed on the Dena variety. A population of *Ischnura heterosticta* from order Odonata also observed. However, this species comprised only 14 individuals in total on all soybean varieties, fewer than *Arigomphus villosipes* with 16 individuals in total on the four soybean varieties. *Mantis religiosa* from order the Mantodea was the rarest species found during the experiment. The most dominant species was *Odontoponera denticulata* from the order Hymenoptera. The total numbers of individual species were 334, 330, 268, and 245 for Dena 1, Detam 3 PRIDA, Deja 1, and Devon 1, respectively (Table 6).

A comparison of the arthropod predator population in soybean plants is shown in Figure 5. The percentage of arthropod predators observed in both Dena 1 and Devon 1 varieties was 27%, while percentage of arthropod predators observed in Detam 3 PRIDA and Deja 1 varieties was 23%. These results indicate that arthropod predators were spread evenly over all soybean varieties.

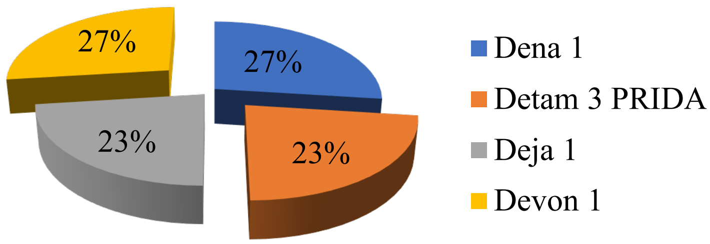


Figure 5. Percentage of predatory arthropods on the four soybean varieties.

These soybean varieties were used in the field as refugia combined with the main crop of chilli plants. Arthropod observations of soybean predators in the ATC field of Sriwijaya University showed that there were 6 orders of 10 families and 19 species of predator arthropods in soybean plants, including *Oxyopes javanus, Oxyopes lineatipes, Oxyopes birmanicus, Oxypes sp.*, *Pardosa sumatrana, Pardosa milvina, Pardosa monticola, Pardosa nemoralis, Pardosa sp.*, *Schizocosa malitiosa, Cocinella repanda, Mycpis spinalcosa, Pardosa milvina, Pardosa monticola, Pardosa nemoralis, Ischnura heterosticta*, *Arigomphus villosipes*, *Mantis religiosa,* and *Odontoponera denticulata.*

The species *Odontoponera denticulata* (Hymenoptera: Formicidae) was found dominantly on soybean plants. The *Odontoponera* genus is popularly known as a predator of fruit flies (Suputa *et al.*, 2007). The second largest number of predatory arthropods in the crop field were from the order Aranae, consisting of the Lycosidae and Oxyopidae families. Lycosidae are wolf spiders or ground spiders, and most of these spiders do not make webs to catch their prey (Ahrens & Kraus, 2006). This spider is known to be very active above ground level, and often climbs plants, especially on low vegetation in search of food (Maramis, 2014). Lycosidae is predominantly found in soybeans, because soy plants are annual herbs that have low vegetation. Lycosidae may select microhabitats based on available moisture, leaf litter, and herbaceous vegetation (Cady, 1984; Richman, 1995). Meanwhile, family Oxyopidae acts as predator on Hemiptera and leaf miners (Rostami *et al.*, 2018). Oxyopidae are canopy occupants, and are diurnal hunter spiders. They run over low shrubs and herbs with great agility, leaping from place to place with a precision exceeded only by the true jumping spiders while hunting their prey (Weems & Whitcomb, 2001).

The order Coleoptera was the third dominant order found in soybean plants, consisting of Coccinelidae, Carabidae, and Staphylinidae. Coccinelidae is a predator of many soft bodied insect pests such as aphids, scale insects, mealy bugs, whiteflies, thrips, jassids, psyllids, small larvae, insect eggs, and phytophagous mites (Kundoo & Khan, 2017). Coccinelidae: *Coccinela repanda* and Staphylinidae: *Paederus fuscipes* were found in both net and pitfall traps, while Carabidae: *Cicindela* sp. was only collected in net traps. Staphylinidae: *Paederus fuscipes* was also found in this research. This beetle is a ground predator, the shiny hot weather affects this insect abundance (Rana *et al*., 2013).

The Asilidae family (Diptera) were found only a few (1.79%). Order Odonata consisted of two species, namely *Ischnura heterosticta* and *Arigomphus villosipes*. Both species comprised a total percentage of 1.86% of all arthropods observed. The Mantodea family was the order with the fewest individuals observed during the experiment. *Mantis religiosa* comprised only 0.37% of all identified arthropods. Family Mantidae is rarely found in soybean plants. Mantodea are very active predators that hunt by sight and are able to switch between ambush and active search (Inoue & Matsura, 1983); therefore, it was difficult to capture this species by net trapping.

This research was conducted in May-July 2019, when the intensity of rainfall ranged from 50-100 mm, i.e. below normal rainfall (BMKG, 2019). May is the beginning of the dry season in the southern Sumatra region with temperatures of 25.7-35.7°C and humidity of 81-98%. Season affects the presence of predatory arthropods; according to Prayogo and Bayu (2018), the arthropod population found during the dry season is larger than that found during the rainy season. Based on the results of this study, *Odontoponera denticulata* (Hymenoptera: Formicidae) was most commonly found in the four soybean varieties. *O. denticulata* is a predatory arthropod that lives on the ground, where rainfall intensity is thought to affect its population.

4. Conclusions

In conclusion, predatory arthropods in soybean plants used as refugia were represented by 6 orders of 10 families and 19 species. The predominant arthropod predator population observed in this research was *Odontoponera denticulata* (Hymenoptera), comprising 73% of the arthropod population. The number of canopy-dwelling arthropod predators was similar in the four soybean varieties. The percentage of predatory arthropods found in Dena 1 and Devon 1 was 27%, while in Detam 3 PRIDA and Deja 1 it was 23%.

Acknowledgements

The authors thank the Agro-Technology Centre, Faculty of Agriculture, Sriwijaya University. This research was funded through the Sriwijaya University research fund based with contract number 0016.UN9/SK.LP2M.PT/2019 dated June 21, 2019 and SP DIPA-042.02.2.400953/2019.

References

Ahrens, L., & Kraus, J. M. (2006). Wolf spider (Araneae, Lycosidae) movement along a pond edge. *Journal of Arachnology*, *34*(3), 532-539.

Aktar, W., Sengupta, D., & Chowdhury, A. (2009). Impact of pesticides use in agriculture: their benefits and hazards. *Interdisciplinary Toxicology*, *2*(1), 1-12.

Biswas, V., & Raychaudhuri, D. (2003). Wolf spiders of Bangladesh: genus Pardosa CL Koch (Araneae: Lycosidae). *Records of the Zoological Survey of India*, *101*(1-2), 107-125.

BMKG. (2019). Analisis Hujan Mei 2019 Prakiraan Hujan Juli, Agustus, dan September 2019. Palembang, Indonesia: Badan Metereologi dan Geofisika Stasiun Klimatologi Kelas I Palembang.

Cady, A. B. (1984). Microhabitat selection and locomotor activity of *Schizocosa ocreata* (Walckenaer) (Araneae: Lycosidae). *Journal of Arachnology 11*, 297-307.

Capinera, J. L. (Ed.). (2008). *Encyclopedia of entomology*. Springer Science & Business Media.

Cutler, B., Jennings, D. T. & Moody, M. J. (1977). Biology and habitats of the lynx spider *Oxyopes scalaris* Hentz (Araneae:Oxyopidae). *Entomology News* 88:87-97.

Desai, S. D., Swaminathan, R., & Desai, V. S. (2017). Effect of habitat manipulation on infestation of paddy leaf folder, *Cnaphalocrocis medinalis* (Guenee). *International Journal of Current Microbiology and Applied Sciences, 6*(10),1469-1477.

Dondale, C. D., & Redner, J. H. (1990). The insects and arachnids of Canada. Part 17. The wolf spiders, nurseryweb spiders, and lynx spiders of Canada and Alaska. Araneae: Lycosidae, Pisauridae, and Oxyopidae. *Publication-Agriculture Canada (English ed.)*, (1856).

Ebeling, A., Meyer, S. T., Abbas, M., Eisenhauer, N., Hillebrand, H., Lange, M., & Weisser, W. W. (2014). Plant diversity impacts decomposition and herbivory via changes in aboveground arthropods. *PloS ONE*, *9*(9), 1-8.

Flint, M. L., & Dreistadt, S. H. (1998). *Natural enemies handbook: the illustrated guide to biological pest control* (Vol. 3386). University of California Press.

Flint, M. L., & Van den Bosch, R. (2012). *Introduction to integrated pest management*. Springer Science & Business Media.

Ganai, S. A., Ahmad H., Sharma D., Sharma S., Khaliq N., & Norboo, T. (2017). Diversity of arthropod fauna associated with marigold (*Tagetes erecta* L.) in Jammu. *Journal of Entomology and Zoology Studies*, 5(5):1940-1943.

Gonçalves, M. F., & Pereira, J. A. (2012). Abundance and diversity of soil arthropods in the olive grove ecosystem. *Journal of Insect Science*, *12*(20), 1-14.

Hanumanthraya, L., & Girish, M. (2009). Impact of different rice agro-ecosystem on spider population dynamics. *Environment and Ecology*, *27*(3A), 1231-1236.

Hassan, K., Pervin, M., Mondal, F., & Mala, M. (2016). Habitat management: a key option to enhance natural enemies of crop pest. *Universal Journal of Plant Science*, *4*(4), 50-57.

Indiati, S. W., & Marwoto. (2017). Penerapan pengendalian hama terpadu (pht) pada tanaman kedelai. *Buletin Palawija*, *15*(2), 87-100.

Inoue, T,. & Matsura T. (1983) Foraging strategy of a mantid, *Paratenodera angustipennis* S: Mechanisms of switching tactics between ambush and active search. *Oecologia 56*, 264-271

Kumar, L., Yogi, M. K., & Jagdish, J. (2013). Habitat manipulation for biological control of insect pests: A review. *Research Journal of Agriculture and Forestry Sciences* ISSN 2320-6063. *1*(10), 27-31.

Kundoo, A. A., & Khan, A. A. (2017). Coccinellids as biological control agents of soft bodied insects: a review. *Journal of Entomology and Zoology Studies*, *5*(5), 1362-1373.

Magurran, A. E. (1988). *Ecological diversity and its measurement*. Princeton university press.

Maramis, R. T. D. (2014). Diversitas Laba-laba (Predator Generalis) pada Tanaman Kacang Merah (*Vigna angularis*) di Kecamatan Tompaso, Kabupaten Minahasa (The diversity of spider (predator generalis) in kidney bean (*Vigna angularis*) plant cultivated in Tompaso District, Minahasa). *Jurnal Bios Logos*, 4(1), 33-40.

New, T. R. (1991). *Insects as predators.* Kensington (AUT): New South Wales University Press.

Pekár, S. (2013). Side effect of synthetic pesticides on spiders. In *Spider Ecophysiology* (pp. 415-427). Springer, Berlin, Heidelberg.

Prayogo, Y., & Bayu, M. S. Y. I. (2018). Status and population of arthropod on mungbean. *In IOP Conference Series: Earth and Environmental Science, The 2nd International Conference on Biosciences (ICoBio)*. Bogor, Indonesia. 8-10 August 2017.

Putra, I. M., Hadi, M., & Rahadian, R. (2017). Struktur Komunitas Semut (Hymenoptera: Formicidae) di Lahan Pertanian Organik dan Anorganik Desa Batur, Kecamatan Getasan, Kabupaten Semarang. *Bioma: Berkala Ilmiah Biologi*, *19*(2), 170-176.

Rana, H., Khan, M. F., Fahim, M., & Tariq, S. A. (2013). Abundance and comparative population fluctuation of rove beetles (*Paederus Fuscipes* and *Paederus Fuscipes*) in Sindh, Pakistan. *Int. J. Biol. Biotech.* 10(2), 271-274.

Richman, D. B. (1995). A comparison of populations of wolfspiders (Araneae, Lycosidae) on two different substrates in southern Florida. *The Journal of Arachnology, 23*, 151-156.

Rostami, E., Madadi, H., Abbasipour, H., & Cuthbertson, A. G. S. (2018). First report of the predatory spider, *Oxyopes lineatus* Latreille (Aranea: Oxyopidae) feeding on the tomato leaf miner, *Tuta Absoluta* (Meyrick) (Lepidoptera: Gelechiidae). *Advances in Food Sciences*, *40*(4), 128-133.

Strand, M. R., & Obrycki, J. J. (1996). Host specificity of insect parasitoids and predators. *BioScience, 46*(6), 422-429. doi:10.2307/1312876

Suputa, Yamane, S., Martono, E., Hossain, Z., & Arminudin, A. T. (2007). *Odontoponera denticulata* (Hymenoptera: Formicidae): a potential biological control agent for true fruit flies (Diptera: Tephritidae) in Yogyakarta, Indonesia. *Jurnal Ilmu-ilmu Pertanian Indonesia*, *3*, 351-356.

Vacante, V., & Bonsignore, C. P. (2017). 3 Natural Enemies and Pest Control. *Handbook of Pest Management in Organic Farming*, 60.

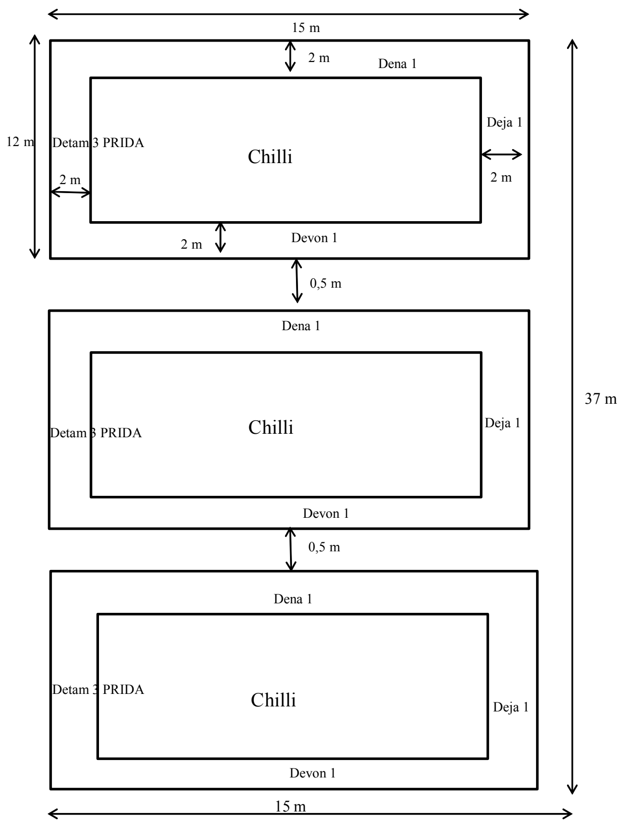
Weems, H. V., & Whitcomb, W. H. (2001). *Green Lynx Spider, Peucetia viridans (Hentz)(Arachnida: Araneae: Oxyopidae)*. University of Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, EDIS.

Zadoks, J. C. (1993). The partial test-comments on the history of thinking about resistance of plants against insects, nematodes, fungi, and other harmful agents. *Current Plant Science and Biotechnology in Agriculture* (Netherlands).

Appendix

Appendix 1. Plot of soybean planting experiment in ATC of Sriwijaya University

Appendix 2. A. Varieties of soybean (A. Dena, B. Detam C. Devon D. Deja)
B. Location captured by Google maps.



Appendix 3. The plot of the four varieties of soybean.