BIODIVERSITAS
Volume 23, Number 4, April 2022
Pages: 1828-1835

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d230415

Impact of soil fertilization on arthropod abundance and diversity on soybean agroecosystem

ROSMA HASIBUAN[1], OLIVIA CINDOWARNI[2], JAMALAM LUMBANRAJA[1], FAVORISEN ROSYKING LUMBANRAJA[3,♥]

[1]Department of Agrotechnology, Faculty of Agriculture, Universitas Lampung. Jl. Prof. Dr. Soemantri Brojonegoro No. 1, Bandar Lampung 35145, Lampung, Indonesia

[2]Agronomy Graduate Program, Faculty of Agriculture, Universitas Lampung. Jl. Prof. Dr. Soemantri Brojonegoro No. 1, Bandar Lampung 35145, Lampung, Indonesia.

[3]Department of Computer Science, Faculty of Mathematics and Natural Sciences, Universitas Lampung. Jl. Prof. Dr. Soemantri Brojonegoro No. 1, Bandar Lampung 35145, Lampung, Indonesia., ♥email: favorisen.lumbanraja@fmipa.unila.ac.id

Manuscript received: 15 February 2022. Revision accepted: 18 March 2022.

Abstract. *Hasibuan R, Cindowarni O, Lumbanraja J, Lumbanraja FR. 2022. Impact of soil fertilization on arthropod abundance and diversity on soybean agroecosystem. Biodiversitas 23: 1828-1835.* Arthropods are biotic components that play an important role in the ecosystem. The field experiment consisting five fertilizer treatments: 100% NPK, 100% organic fertilizer, 100% NPK and 50% organic fertilizer, 50% NPK and 100% organic fertilizer, and no fertilizer was conducted to study the arthropod abundance and diversity in soybean agroecosystem. Pitfall traps were set up for collecting soil arthropods, while data for foliar arthropods were obtained by visual observation. During the study, the soybean agroecosystem was inhabited by 2756 arthropods that belong to 64 families. The results of arthropod community composition indicated that soil and foliar arthropods were most dominated by Coleoptera and Hemiptera. Predators were the most abundant in pitfall traps and herbivores with a visual inspection. Additionally, predators had the highest number of families. Soil fertilizer treatments had a significant impact on the abundance of foliar arthropods and soil arthropods. The highest numbers of foliar arthropods were found in soybean plants treated by inorganic fertilizer (NPK) either alone or in combination. However, soil arthropods were most abundant in soybean treated by organic fertilizer. The application of organic fertilizers to the soybean agroecosystem was able to increase the diversity of ground-dwelling arthropods and foliage-inhabiting arthropods across sampling periods.

Keywords: Arthropod abundance, arthropod diversity, fertilizer, soybean agroecosystem

INTRODUCTION

Soybean is one of the most important cultivated crops worldwide. Soybean is primarily used for producing oil and protein for human and animal consumption (Asodina et al. 2020; Da Silva et al. 2020; Harsono et al. 2021). In Indonesia, soybean is also considered a valuable crop (Lestari et al. 2018) and has become the third major commodity after rice and maize (Hasan et al. 2015). One of the main factors that cause low soybean production is pest attack and damage. Several arthropod pests attack soybean starting from the early vegetative growth until the late reproductive stage (Greene et al. 2021; Thrash et al. 2021). For soybean growers, pesticides become the predominant pest management program in controlling soybean pests (Biondi et al. 2012; Hodgson et al. 2012; Karenina et al. 2019; Majidpour et al. 2020). However, excessive use of pesticides generates many ecological problems, agricultural environment contamination, natural enemy destruction, and the appearance of pest resistance to pesticides (Biondi et al. 2012; Jia et al. 2012; Gill and Garg 2014; Quarcoo et al. 2014).

Arthropods are biotic components that have an important role in the ecosystem (Gonçalves and Pereira 2012; Mattson 2012; Culliney 2013; Elie et al. 2018). The arthropod community in soybean fields is known to have different ecological roles, they include herbivorous pests, natural enemies (predators and parasitoids), and detrivores (Adams et al. 2017; Karenina et al. 2019; Anggraini et al. 2020; Anggraini et al. 2021). These different groups can perform stability in the soybean field ecosystem by building a complex food web (Mattson 2012; Burgio et al. 2015; Riggi and Bommarco 2019). Maintaining ecological stability is mandatory for the development of biological control. The use of natural enemies in biological control, such as predators and parasitoids, is one of the important pest management strategies in controlling the pest population (Hodgson et al. 2012; Dunbar et al. 2016; Adams et al. 2017; Redlich et al. 2019). The concept of agroecosystem management by maintaining a complex food web is expected to create a resilient agroecosystem that can prevent the explosion of pests so that it can result in sustainable pest management (Dominik et al. 2018; Elsa et al. 2019). On the other hand, arthropods are highly responsive to environmental changes, such as fertilizers, pesticides, weed management, cover crop, grazing management, pest management, prey availability, plant composition. Many publications have reported that these cultivation practices have been shown to have an impact on arthropod populations in an agroecosystem: grazing management systems on coleopteran dung beetles

(Magdoff and van Es 2021), mulches, and pest management on arboreal arthropod in chili pepper (Herlinda et al. 2021), weed management on arthropod communities (Bryant et al. 2013), plant composition on arthropod pest and predator abundance (Parry et al. 2015), insecticide on not-targeted arthropods (Hanif et al. 2020), tillage and chlorpyrifos on soil arthropods (Cardoza et al. 2015), insecticides on the abundance of canopy arthropods (Prabawati et al. 2019). In addition, Culliney (2013) reported that soil nutrient has an impact on arthropod communities by enhancing arthropod growth, fecundity, survival, and density. Fertilizer is one of the essential components for agricultural crop production (Magdoff and van Es 2021). As a part of cultural control, soil fertilization management can have a significant effect on the physiological performance of crop plants to arthropods pest attack. Generally, arthropods biodiversity in a soybean ecosystem plays an important role in maintaining ecological stability in the soybean field ecosystem. Hence, the research to investigate the effect of soil fertilization on the abundance and diversity of arthropods in the soybean agroecosystem was conducted.

MATERIALS AND METHODS

The experimental site

This research was conducted at the Integrated Agricultural Experimental Stations, the University of Lampung, Bandar Lampung, Indonesia, from June to November 2017. The experimental site is situated at 5°22'11.38" S-105°14'25.96" E, at an altitude of 106 m above sea level. The plot area was 450 m^2 (25 x 18 m) assigned into 15 experimental plots. The area for this research was prepared by plowing the field, then loosening and softening the soil, after that, the soil was leveled and shaped perpendicularly. Each plot size was 4 x 3 m with 0.5 m spacing between plots. Anjasmoro, one of the commercial soybean varieties, was used in this experiment. According to Harsono et al. (2021), Anjasmoro is one of the soybean varieties that is broadly adaptive in all land conditions. The surface condition of each plot was marked by making a hole for the suitable plant to grow. Three seeds were placed in each hole, with 15 x 45 cm spacing. The five treatment descriptions and their application rates were: T0: no fertilization; T1 (100% NPK = 50 kg ha^{-1} Urea + 80 kg ha^{-1} TSP + 150 kg ha^{-1} KCl); T2 (100% organic fertilizer = 10,000 kg ha^{-1} compost); T3 (100% NPK) + (50% organic fertilizer = 5000 kg ha^{-1} compost); D (100% organic fertilizer) + (50% NPK = 25 kg ha^{-1} Urea + 40 kg ha^{-1} TSP + 75 kg ha^{-1} KCl). Each treatment was replicated three times. Therefore, the total number of experimental units was 15 assigned to each experimental plot prepared before. The layout of the soil treatments was arrayed in a randomized block design (RBD). In this study, organic fertilizer was compost, while NPK was a commercial chemical fertilizer. The organic and TSP fertilizer were applied one time after planting, but Urea and KCl were applied twice: 1 and 3 weeks after planting. Both organic and inorganic fertilizer spread above the soil surface near surrounding soybean plants according to each treatment description and its application rates.

Arthropod sampling

In this study, pitfall samplings were used to collect soil arthropods while direct visual observations to assess foliar arthropods. Adams et al. (2017) reported that soil arthropod was collected by using a pitfall trap, while foliar arthropod measurement was accomplished by visual inspection. A plastic cup with a diameter of 7 cm was used for preparing a pitfall trap. The plastic cups were dug into the soil with the lip even with the soil surface to ensure that there was no gap between the cup and the ground. Previously, the plastic cup was filled within a half volume of fluid, water mixed with 96% ethanol. A roof of the pitfall trap was set up by using mica plastic supported by four bamboos. This roof was necessary for preventing rainwater to enter the cup. From the middle rows of soybean plants, five soybean plants were selected randomly and labeled as sampled plants. Five pitfall traps were set up near the sample plants. The traps were installed in the evening and observed 24 hours later. Sampling was conducted twice: at V3 (three nodes) and R3 (beginning pod) stages. Captured individuals using pitfall traps were put into glass vials containing 76% ethanol solution and labeled to avoid mistaken identification in the laboratory.

Above-ground (foliar) arthropods were counted with visual observation and hand collection. The selected plants from each treatment plot were gently turned over, and soybean canopies were observed thoroughly for at least 5 minutes for each sample. The numbers of arthropods on each sampled plant were counted quickly. The taxonomic identity of each arthropod was also recorded, however unknown species were placed in a 5-ml plastic tube individually for later identification. A magnifying glass was used to look for small arthropods. In a particular case, if a sample plant had an enormous number of arthropods (like aphids and another sap-feeding insect), ground cloth would be set up for scouting them. As previously explained, sampling of foliar arthropods was conducted twice: at V3 and R3 stages.

All captured individuals using pitfall trap and hand collection were brought to the Arthropod Pests Laboratory, Faculty of Agriculture, Lampung University for arthropod identification. All collected arthropod individuals were identified at a family level. Arthropod identification was performed under a dissecting stereo-microscope. Data of arthropods were grouped based on their feeding guilds, comprised of herbivores, predators, parasitoids, detrivores, and arthropod order. In addition, the number of individuals of each tropic level from each sampled unit was recorded.

Data analysis

The abundance of arthropods was generated from the number of individuals in each treatment, while the diversity of arthropods was using the data of arthropods variety on family level. The number of individuals (the abundance) in each treatment was analyzed using Analysis of Variance, followed by the comparison of means with least significant difference (LSD) test ($p<0.05$) using the software SPSS

Statistics version 20.0. The number of families in each feeding guild was recorded and presented in the table. The relative abundance of arthropods on each feeding guild was calculated by dividing the number of individuals in the same feeding guild by total individual catches. The same method was done for relative abundance arthropods on each dominant order. The two relative abundances were presented in the form of a graphic.

The arthropod diversity data were analyzed by using non-parameter statistics. Arthropod diversity was calculated by the Shannon-Wiener index (H') and Pielou evenness index (E) (Magurran 2004). The value of H' is given by:

$$H` = -\sum_{i=1}^{s} (Pi)\ \ln Pi$$

Where, Pi is the proportional number of individuals in i^{th} species in total sample.

The value E is given by, $E = \frac{H'}{\ln S}$

Where, H' is Shannon-Wiener index and S is the number of species.

RESULTS AND DISCUSSION

Arthropod community composition in soybean plots

During the study, there were 2756 arthropod specimens (insects and spiders) collected from the soybean agroecosystem, of which 1654 were cached in a pitfall trap and 1102 arthropods by visual inspections. All arthropods in the samples were classified by trophic level, as herbivore, predator, parasitoid, and detrivore, and by order of arthropods presented in Figures 1 and 2. In general, the arthropod community composition in soybean plots was dominated by insects. This total individual was classified further into arthropod orders. The results showed that the dominant orders by the percentage of total specimens in pitfall traps were 31.6% Coleoptera, 26.5% Araneae, 9.2% Orthoptera, 7.2% Hemiptera, 6.5% Hymenoptera, 4.6% Lepidoptera. Meanwhile, the percentage of dominant order collected by visual observations were 22.2% Hemiptera, 20.0% Coleoptera, 14.9% Lepidoptera, 9.2% Araneae, 6.6% Homoptera, 5.5% Hymenoptera, 4.0% Orthoptera (Figure 1). This result indicated that different sampling methods assess different dominant arthropod orders. Homopteran insect pests only appeared in visual inspection sampling, which becomes the fifth dominant order of foliar arthropods. In the meantime, spiders (Araneae) were collected in two sampling methods. In pitfall trap sampling, Araneae was the second dominant arthropods (26.5%), but in visually inspected sampling was the fourth dominant order (9.2%). In general, most homopteran insects act as herbivorous arthropods, while spiders in the Araneae order act as predatory arthropods. Generally, the most dominant order of soybean arthropods found in pitfall trapping and visually inspection was Coleoptera (31.6%) and Hemiptera (22.2%). This result indicated that soil arthropods in the soybean agroecosystems were most dominated by Coleoptera, conversely, foliar arthropods were most dominated by Hemiptera. Anggraini et al. (2021) reported that the order of phytophagous insects found in the soybean canopy was Orthoptera, Hymenoptera, Coleoptera, Lepidoptera, and Hemiptera. On the other hand, the results of Adams et al. (2017) showed that the dominant orders of soil arthropods found in pitfall traps during the soybean growing season were Acari, Collembola, Hymenoptera, Coleoptera, Orthoptera, Diptera.

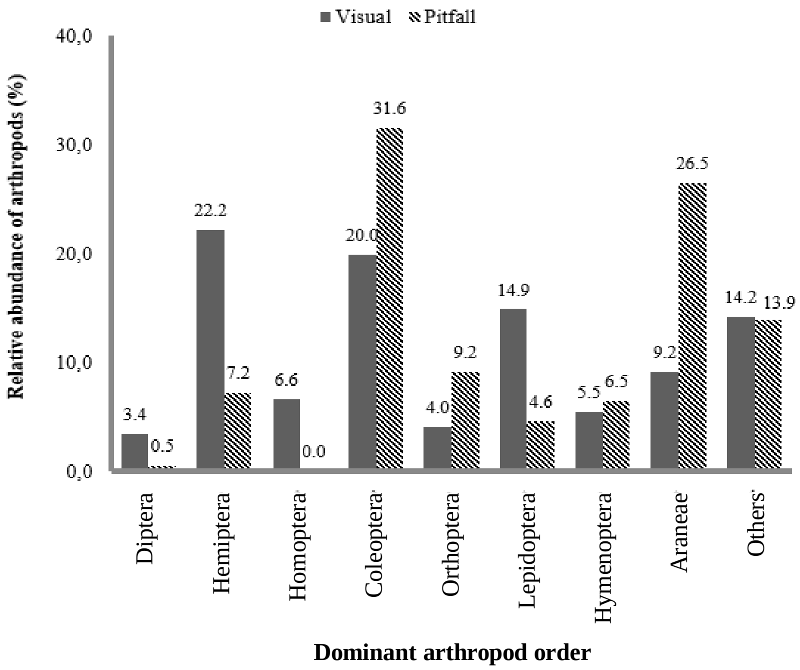

Figure 1. Dominant arthropod orders sampled by pitfall trapping and visual inspections from soybean agroecosystem

All arthropods collected from the soybean agroecosystem during the study were further separated according to their feeding characteristics and tropic positions, in this case, it had been classified into four functional groups, herbivores (pests), predators, parasitoids, and detrivores. Overall results of the relative abundance showed that 36.29% soybean herbivores, 40.58% predators, 0.63% parasitoids, and 22.50% detrivores were collected by pitfall trapping. Meanwhile, arthropods' relative abundance by visual observations was 48.78% soybean herbivores, 41.88% predators, 8.48% parasitoids, and 0.86% detrivores (Figure 2). This result is in line with data presented in Figure 1, in which the most dominant order of soil arthropods was Coleoptera which mostly acts as predators and Hemiptera was, the most dominant order of foliar arthropods, which mostly act as herbivorous pests. These results indicated that the arthropod community composition in soybean agro-ecosystem in pitfall trap was dominated by ground-dwelling arthropods with a functional group as predators, but in visual observation was foliage-inhabiting arthropods with feeding guild as herbivores. Meithasari et al. (2014) reported that *Aphis* sp. (Hemiptera), the uppermost abundance of insect pests of soybean plants and coccinellids (Coleoptera), were the most dominated predators of soybean crops. Different results were found by Anggraini et al. (2021), who reported that the most abundant phytophagous insect act as pests in soybean canopy was Lepidoptera, while in pitfall trap was hymenopteran ants that act as an entomophagous insect. Previously, Anggraini et al. (2020) reported that the species *Odontoponera denticulata* in hymenopteran order was found to be a dominant predator on soybean plants.

Foliage and soil arthropods abundance

In this study, the abundance of arthropods refers to the number of individual arthropods found at each particular plant sample. In general, the data in Table 1 indicated that the number of arthropods increased as the soybean plant grew from vegetative to reproductive stage. For instance, the mean number of foliar arthropods on soybean fertilized with the full dose of inorganic fertilizer (NPK), T1, was 39.51 ± 12.23 individuals /5 plants at V3-stage increased to 86.67 ± 21.67 individuals / 5 plants at R3-stage (Table 1). Similar results also appeared in all other treatments. This finding indicated that the growth of arthropod populations was closely associated with plant performance. At V3-stage (3rd trifoliate), soybean plants only have foliage, while at R3-stage (beginning pod), soybean plants already have new pods. This result demonstrated that the more diverse structure of the plant increased the habitat space for arthropods and became an important factor for contributing to higher arthropod colonization. During the study, we observed that foliar arthropods of soybean are mostly dominated by sap feeders and defoliating insect pests. Sap feeding insect pests predominantly belonged to the homopteran and hemipteran order, while defoliating insect pests were mostly lepidopteran and coleopteran insect pests. Based on direct visual observation, the most common insect pest that sucks the juice of soybean plants were aphids (Homoptera: Aphididae), bean bugs (Hemiptera: Alydidae), and green stink bug (Hemiptera: Pentatomidae). Meanwhile, the insect pest that consumed the soybean leaves was mostly cotton leafworm (Lepidoptera: Noctuidae). Besides insect pests, the soybean canopy is also inhabited by predators. The seven-spot ladybird (Coleoptera: Coccinellidae) was the most predominant predator that fed on other insects on soybean.

This result indicated that chemical fertilizer (NPK) increased the abundance of the foliar arthropods in the soybean agroecosystem. This finding implies that fertilizer treatments can affect the physiology of crop plants that support arthropod colonization. Nitrogen is one of the important soil nutrients that have a significant effect on foliar insect arthropods. Plant with high nitrogen content was characterized by vigorous growth and succulence tissue, which is favourable for sucking insect pests to inhabit. According to Rhodes et al. (2019), the quantity of nitrogen in host plants is one of the important factors in the development and growth of insect herbivores, especially sap-feeding insects. The results of Hasibuan and Lumbanraja (2012) showed that soil fertility management had an impact on the sap-feeding aphid population on soybean plants. Other publications also reported that the nutritional value of the host plant could also influence other insects with different feeding guilds. The results of Pope et al. (2011) revealed that conventional fertilizer treatments affected the aphid parasitoid *Diaeretiella rapae*.

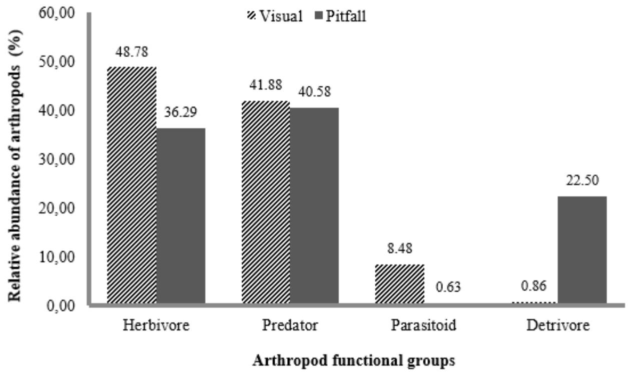

Figure 2. Relative abundance of arthropods by each functional category (feeding guilds) in soybean agroecosystem

Table 1. Mean number of individual foliar arthropods caught (Mean ± SE) at V3 and R3 stage of soybean

Treatments	Number of arthropods / 5 plants	
	V3-Stage	R3-Stage
T0	20.55 ± 5.13 a	59.31 ± 19.45 a
T1	39.51 ± 12.23 bc	86.67 ± 21.67 bc
T2	26.40 ± 7.15 a	79.08 ± 19.69 b
T3	41.00 ± 21.14 c	90.33 ± 29.74 c
T4	31.67 ± 8.23 b	83.67 ± 27.71 b
F Value	419.15	4.89
Pr > F	< 0.0001	0.0272
LSD	2.3567	16.59

Note: T0: no fertilizer; T1: 100% NPK; T2: 100% organic fertilizer; T3: 100% NPK + 50% organic fertilizer; T4: 100% organic fertilizer + 50% NPK; Same letters after means within the same column are the sign for non - significance difference based on LSD test, with significance level 5%.

The data in Table 2 indicated the number of soil arthropod in agroecosystem collected by pitfall trap sampling vary among treatment. If we compared this result with foliar arthropods, it is clear that the number of soil arthropods (Table 2) was higher than foliar arthropods (Table 1). This finding demonstrated that soil arthropods were more abundant compared to foliar arthropods in the soybean agroecosystem. Moreover, the result indicated that fertilizer treatment had a significant impact on the mean number (abundance) of soil arthropods at V3 stage ($F_{4,8}$: 648.63; $P<0.0001$) a R3 stage and ($F_{4,8}$: 616.46; $P<0.0001$), respectively (Table 2). At the V3 stage, the highest number of soil arthropods was 85.14 ± 13.86 individuals / 5 traps, and it was found on the soybean plant fertilized with a combination full dose of organic fertilizer with a half dose of NPK (T4). This number was significantly higher compared to other treatments except for the number of arthropods (77.14 ± 18.15 individuals / 5 traps) soybean plants that had been organic fertilizer with full-dose treatment (T2). The same results also appeared at R3-stage, the highest number of ground-dwelling arthropods was 283.80 ± 35.52 individuals /5 traps, collected from the treatment T4 (combination 100% organic fertilizer and 50% NPK) followed by the treatment T2 (100% organic fertilizer) with the mean number of arthropods 269.36 ± 32.25 individuals / 5 traps.

In this study, the organic fertilizer we used was compost. For soil-dwelling arthropods that act as a detrivore, organic matter can be used as a source of nutrients by breaking down the organic material. The most common detrivores collected during the study were springtails in the family of Cylistidae. In gaining the nutrients and energy, the springtails eat dead or decaying plants or animals in the soil. In the same habitat, soil predators get the energy by feeding other insects or mites in the soil. The presence of other animals such as springtails can be another alternative prey for the predators to supply their food. The most common predators we found on the ground in the soybean agroecosystem were ants in the Hymenoptera order. Based on this result, it can be inferred that applying a certain amount of organic fertilizer can promote soil arthropods colonization, which increases the abundance of soil arthropods in the soybean agroecosystem. Magdoff and van Es (2021) stated in their book that soils with high organic matter increase the abundance of ground-dwelling arthropods. Other publications reported that organic crop production increased the abundance of arthropods: carabids and other soil arthropods in a horticultural vegetable agroecosystem (Burgio et al. 2015) and soil arthropods in the olive grove ecosystem (Gonçalves and Pereira 2012).

Foliar and soil arthropods diversity

During the study, there were 64 families of arthropods that inhabited the soybean agroecosystem, of which there were 25 families of herbivores, 27 families of predators, 5 families of parasitoids, and 7 families of detrivores (Table 3). The data in Table 3 were generated by classifying all families during the study according to their feeding guilds to give general information about the variety of arthropod presence during the study. The data in Table 3 were further used to measure arthropod diversity in the soybean agroecosystem. Inhibiting by 64 families, it can be assumed that soybean agroecosystem had high biodiversity. Other results presented in Table 3 indicated that the highest number of arthropod families was predators, followed by herbivores. This result implies that predatory arthropods were the most diverse in the soybean agroecosystem. Anggraini et al. (2021) reported that there were 9 families found in a net trap of soybean canopy as phytophagous (pests) and entomophagous (predators) insects, and there were 6 families collected from pitfall traps in soybean cultivation. Moreover, Meithasari et al. (2014) reported that there were 4 dominant families of soybean pests found in soybean plantations, while the dominant predators were 3 families.

The diversity of arthropods in the soybean agroecosystem was calculated by using taxon-based methods, in our case, using families from the data presented in Table 3. Magurran (2004) in her book, stated that diversity measured by taxon-based methods is called taxonomic diversity. The two indices, diversity index H′ and evenness index E were calculated to measure the aspect of arthropod diversity in soybean agroecosystem and the results had been presented in Table 4 (foliar arthropod diversity) and Table 5 (soil arthropod diversity). The two H′ and E indices are complementary. Measuring diversity with only diversity index without evenness index is meaningless. The value of H′ gives the information on how diverse the species, in our study families, are in a given agroecosystem. The higher the index, the more diverse the species are in the habitat. In general, the value of H′ ranges from 0 to 5. However, in order to understand the meaning of a given value of H', the evenness index E (or equitability) also should be measured. Evenness index refers to the relative abundance of species in one habitat. The value of E ranges from 0 to 1. If the value of E is close to 1, this means all the species in that habitat are equally distributed.

Table 2. Mean number of individual soil arthropods caught (Mean ± SE) at V3 and R3 stage of soybean

Treatments	Number of Arthropods / 5 Traps	
	V3-Stage	R3-Stage
T0	27.27 ± 8.15 a	91.33 ± 27.45 a
T1	37.51 ± 9.21 ab	117.04 ± 25.24 b
T2	77.14 ± 18.15 c	269.36 ± 32.25 c
T3	43.00 ± 18.73 b	179.50 ± 37.29 d
T4	85.14 ± 13.86 c	283.80 ± 35.52 e
F Value	648.63	616.46
Pr > F	< 0.0001	< 0.0001
LSD	3.3943	12.463

Note: T0: no fertilizer; T1: 100% NPK; T2: 100% organic fertilizer; T3: 100% NPK + 50% organic fertilizer; T4: 100% organic fertilizer + 50% NPK; Same letters after means within the same column are the sign for non - significance difference based on LSD test, with significance level 5%.

Table 3. The arthropods families separated into four guilds observed in a soybean agroecosystem

Feeding guild	Family (common name)	Total
Herbivore (pest)	Aphididae (aphids), Agromyzidae (leaf-miner flies), Tephritidae (fruit flies), Lygaeidae (seed bugs), Plataspidae (bean plastaspids), Cydnidae (burrower bugs), Coreidae (coreid bugs), Pentatomidae (stink bugs), Alydidae (broad-headed bugs), Membracidae (treehoppers), Cicadellidae (leafhoppers), Delphacidae (planthoppers), Aleyrodidae (whiteflies), Coccoidea (scale insects), Pyralidae (snout moths), Noctuidae (armyworms), Erebidae (tiger moths, tussock moths), Carabidae (ground beetles), Anthicidae (ant-like beetles), Geometridae (geometrid moths), Chrysomelidae (leaf beetles), Cerambycidae (longhorn beetles), Gryllidae (true crickets), Acrididae (grasshoppers), Gryllotalpidae (mole crickets)	25
Predator	Syrphidae (hoverflies), Asilidae (robber flies), Sphecidae (thread-waisted wasps), Apidae (digger bees), Vespidae (yellowjackets), Argidae (sawflies), Eurytomidae (eurytomid wasp), Formicidae (ants), Reduviidae (assassin bugs), Miridae (mirid bugs), Staphylinidae (rove beetles), Carabidae (ground beetles), Coccinellidae (ladybirds), Forficulidae (common earwigs), Anisolabididae (ring-legged earwigs), Tettigoniidae (katydids), Lycosidae (wolf spiders), Oxyopidae (lynx spiders), Tetragnathidae (long-jawed spiders) Linyphiidae (money spiders), Thomisidae (crab spiders), Salticidae (jumping spiders), Araneidae (orb-weaver spiders), Pisauridae (nursery web spiders), Clubionidae (sac spiders), Mantidae (praying mantis), Libelluidae (skimmers).	27
Parasitoid	Braconidae (braconid wasps), Ichneumonidae (ichneumon wasps), Scelionidae (scelionid wasps), Tachinidae (tachinid flies), Eurytomidae (eurytomid wasp).	5
Detrivore	Culicidae (mosquitoes), Scarabaeidae (scarab beetles), Isotomidae (smooth springtails), Spirobolidae (North American millipede), Cylistidae (cylistid isopod), Xystodesmidae (xystodesmid millipedes), Ectobiidae (wood cockroaches).	7

The value of the two indices for foliar arthropods was varied among all fertilizer treatments across all sampling periods (Table 4). In general, the value of H' in treated plants with various fertilizers was higher than that on check plants without fertilizer. At the V3 stage, the highest value of H′ for foliar arthropods was 3.30 and it was found on soybean plant fertilized with the combination of the full dose of organic fertilizer and half dose of NPK (T4), followed by H': 2.88 found on soybean plant fertilized with the full dose of organic fertilizer (T2) (Table 4). While the lowest value of H′ foliar arthropods was 2.55 assessed from soybean plants without fertilizer. The same results also appeared at the R3-stage, in which the highest H′ value, 3.45 found on treatment T4 (100% organic fertilizer + 50% NPK) followed by treatment T2 (100% organic fertilizer), with H': 3.42. The lowest value of H′ at R3-stage was 2.50 found on soybean plants without fertilizer (Table 4).

Data in Table 4 also indicated that the value of evenness index E of foliar arthropods ranged from 0.47 to 0.71 at two sampling periods. The value of E in treated plants with various fertilizers was higher than on check plants without fertilizer. At the V3 stage, the highest value of E was 0.69 found from the soybean plant fertilized with the combination of the full dose of organic fertilizer and half dose of NPK (T4), followed by E: 0.63 found on soybean plants fertilized with the full dose of organic fertilizer (T2). Meanwhile, the lowest value of E (0,58) was found on soybean plants without fertilizer (Table 4). The same results also appeared at the R3-stage, with the highest E value, 0.76 found on treatment T4 (100% organic fertilizer + 50% NPK) followed by treatment T2 (100% organic fertilizer), with E: 0.72. The lowest value of E for foliar arthropods was 0.53 found on soybean plants without fertilizer (Table 4).

The results presented in Table 4 showed that the value of two indices, H' and E, at the R3 stage was higher compared to the V3 stage. This result indicated that the growth of soybean plants was related to the foliar arthropod diversity. The more diverse structure of the soybean plant at the R3-stage (beginning pod) provided more habitat space for arthropods to inhabit and became an important factor for contributing to the high arthropod diversity. In addition, the soybean fertilized with the combination of the full dose of organic fertilizer with a half dose of NPK resulted in a higher diversity index H′ and evenness index E of arthropods that inhabit the canopy soybean crops. These findings indicated that applying organic fertilizer to the crops gave a higher diversity of foliar arthropods in the soybean agroecosystem. These results were supported by Adams et al. (2017), who showed that the higher diversity indices of foliar soybean arthropods were found in organic farming systems. Bhatt et al. (2018) reported that the biodiversity of insect pests and their predators increased on organic okra agroecosystem.

Data presented in Table 5 is the information of soil arthropods. The results demonstrated that the value of diversity index H′ ranged from 2.21 to 3.59 at two sampling periods. At the V3 stage, the highest value of H′ was 3.18 and it was found on soybean plant fertilized with the combination of the full dose of organic fertilizer with a half dose of NPK (T4) followed by H': 2.99 that it was found on soybean plant fertilized with the full dose of organic fertilizer (T2) (Table 5). While the lowest value of H′ soil arthropods was 2.21, and it was caught from soybean plants without fertilizer. The same results also appeared at R3-stage, the highest H′ value, 3.59, was found on treatment T4 (100% organic fertilizer + 50% NPK). However, the lowest value of diversity index H′ at R3-stage was 2.57 and it was found on soybean plants without fertilizer.

Table 4. The effect of soil treatment on the value of diversity H' and evenness E of foliar arthropods at V3 and R3 stage soybean growth

Plant stages	Diversity indices	Soil treatment				
		T0	T1	T2	T3	T4
V3	H`	2.55	2.84	2.88	2.76	3.30
	E	0.58	0.60	0.63	0.58	0.69
R3	H`	2.50	3.23	3.42	2.94	3.45
	E	0.53	0.68	0.72	0.62	0.76

Note: T0: no fertilizer; T1: 100% NPK; T2: 100% organic fertilizer; T3: 100% NPK + 50% organic fertilizer; T4: 100% organic fertilizer + 50% NPK

Table 5. The effect of soil treatment on the value of diversity H' and evenness E of soil arthropods at V3 and R3 stage soybean growth

Plant stages	Diversity indices	Soil treatment				
		T0	T1	T2	T3	T4
V3	H`	2.21	2.66	2.99	2.56	3.18
	E	0.47	0.56	0.61	0.54	0.67
R3	H`	2.57	3.23	3.42	2.94	3.59
	E	0.51	0.62	0.66	0.59	0.71

Note: T0: no fertilizer; T1: 100% NPK; T2: 100% organic fertilizer; T3: 100% NPK + 50% organic fertilizer; T4: 100% organic fertilizer + 50% NPK

On the other hand, the value of evenness index E of soil arthropods ranged from 0.51 to 0.71 at two sampling periods (Table 5). At the V3 stage, the highest value of E was 0.67, and it was found from the soybean plant fertilized with the combination of the full dose of organic fertilizer with a half dose of NPK (T4) followed by E: 0.61 that it was found on soybean plants fertilized with the full dose of organic fertilizer (T2). However, the lowest evenness index value was 0.47, it was caught on soybean plants without fertilizer (Table 5). At the R3 stage, the highest value of E was 0.71 was found on treatment T4 (100% organic fertilizer + 50% NPK). However, the lowest value of diversity index H′ at R3-stage was 0.51 and it was found on soybean plants without fertilizer (Table 5).

Based on the value of two indices, H' and E, it was proved that applying the organic fertilizer to the soil increased the variety of soil arthropods. For soil-dwelling arthropods that act as a detrivore, organic matter has been used as a source of nutrients by eating dead or decaying plants or animals in the soil. In the same habitat, soil predators get the energy by feeding other insects or mites in the soil that mainly act as detrivores. The presence of other animals that act as detrivores can be another alternative prey for the predators to supply their food. The results of the existence of a wide variety of arthropods with different feeding guilds lead to the more complexity of a food web. It is an important factor in maintaining the ecological stability of the soybean agroecosystem. Other publications also reported that organic farming system increased the diversity of arthropods leading to ecological stability: higher diversity of soil arthropods in soybean organic farming systems organic (Adams et al. 2017), vegetable system on carabids and other soil arthropods (Burgio et al. 2015); soil fauna in temperate forests (Elie et al. 2018), crop diversity through organic farming on natural enemies (Redlich et al. 2019), organic grazing management diversity of dung beetles (Wagner et al. 2021).

In conclusion, during the study, there were a total of 2756 arthropod specimens collected from the soybean agroecosystem, of which 1654 were cached in pitfall trap and 1102 arthropods by visual inspections. Based on arthropod's taxa, there were 64 families of arthropods inhabited the soybean agroecosystem during the study, of which there were 25 families of herbivores, 27 families predators, 5 families of parasitoids, and 7 families detrivores. Predatory arthropods were the most diverse in taxa on the family base in the soybean agroecosystem. The dominant arthropod order was Coleoptera sampled by pitfall trapping and Hemiptera sampled by visual inspections. The population of arthropods in each category of sampling increased as the soybean plant grew from vegetative to reproductive stage. Meanwhile, the number of arthropods was significantly affected by fertilizer treatments across sampling periods (V3 and R3 stage) collected by visual inspections and pitfall trapping. Application inorganic fertilizer NPK, either in single or in combination, in soybean crops significantly increased the abundance of the foliar arthropods. On the other hand, applying organic fertilizers (compost) significantly increased the soil arthropod population. The arthropod's taxa used for measuring diversity was family level. The value diversity index H′ and evenness index E for foliar and soil arthropods were higher at the R3 stage than that on at V3 stage. The highest diversity of foliage inhabiting arthropods and ground-dwelling arthropods was found in soybean agroecosystem fertilized with the combination of the full dose of organic fertilizer and half dose of NPK.

ACKNOWLEDGEMENTS

The authors express the deepest gratitude to the Dean of Agriculture Faculty and Rector of the University of Lampung. This research was funded by Professor Research Grant of Lampung University, Indonesia.

REFERENCES

Adams PR, Orr DB, Arellano C, Cardoza YJ. 2017. Soil and foliar arthropod abundance and diversity in five cropping systems in the coastal plains of North Carolina. Environ Entomol 46 (4): 771-783. DOI: 10.1093/ee/nvx081.

Anggraini E, Herlinda S, Irsan C, Harun U. 2020. Diversity of predatory arthropods in soybean (*Glycine max* L.) refugia. J Agric Sci Technol 4 (2): 101-117. DOI: 10.32530/jaast.v4i2.165.

Anggraini E, Anisa WN, Herlinda S, Irsan C, Suparman S, Suwandi S. 2021. Phytophagous insects and predatory arthropods in soybean and zinnia. Biodiversitas 22 (3): 1405-1414. DOI:10.13057/biodiv/d220343.

Asodina FA, Adams F, Nimoh F, Weyori EA, Wongnaa CA, Bakang JE. 2020. Are non-market benefits of soybean production significant? An extended economic analysis of smallholder soybean farming in Upper

West region of northern Ghana. Agric Food Secur 9: 13. DOI: 10.1186/s40066-020-00265-7.
Bhatt B, Joshi S, Karnatak AK. 2018. Biodiversity of insect pests and their predators on okra agroecosystem. J Pharmacogn Phytochem 7: 84-86. DOI: 10.20546/ijcmas.2018.709.091.
Biondi A, Desneux N, Siscaro G, Zappalà L. 2012. Using organic-certified rather than synthetic pesticides may not be safer for biological control agents: Selectivity and side effects of 14 pesticides on the predator *Orius laevigatus*. Chemosphere 87: 803-812. DOI: 10.1016/j.chemosphere.2011.12.082.
Bryant A, Brainard DC, Haramoto ER, Szendrei Z. 2013. Cover crop mulch and weed management influence arthropod communities in strip-tilled cabbage. Pest Manag 42: 293-306. DOI: 10.1603/EN12192.
Burgio G, Campanelli G, Leteo F, Ramilli F, Depalo L, Fabbri R, Sgolastra F. 2015. Ecological sustainability of an organic four-year vegetable rotation system: Carabids and other soil arthropods as bioindicators. Agroecol Sust Food 39 (3): 295-316. DOI: 10.1080/21683565.2014.981910.
Cardoza YJ, Drake WL, Jordan DL, Schroeder-Moreno MS, Arellano C, Brandenburg RL. 2015. Impact of location, cropping history, tillage, and chlorpyrifos on soil arthropods in peanut. Environ Entomol 44 (4): 951-959. DOI: 10.1093/ee/nvv074.
Gonçalves MF, Pereira JA. 2012. Abundance and diversity of soil arthropods in the olive grove ecosystem. J Insect Sci 12 (20): 1-14. DOI: 10.1673/031.012.2001.
Culliney TW. 2013. Role of arthropods in maintaining soil fertility. Agriculture 3 (4): 629-659. DOI:10.3390/agriculture3040629.
Da Silva RFB, Batistella M, Moran E, Celidonio OLD, Millington JDA. 2020. The soybean trap: challenges and risks for Brazilian producers. Front Sustain Food Syst 4: 12. DOI:10.3389/fsufs.2020.00012.
Dominik C, Seppelt R, Horgan FG, Settele J, Václavík T. 2018. Landscape composition, configuration, and trophic interactions shape arthropod communities in rice agroecosystems. J Appl Ecol 55 (5): 2461-2472. DOI: 10.1111/1365-2664.13226.
Dunbar MW, Gassmann AJ, O'Neal ME. 2016. Impacts of rotation schemes on ground-dwelling beneficial arthropods. Environ Entomol 45 (5): 1154-1160. DOI: 10.1093/ee/nvw104.
Elie F, Vincenot L, Berthe T, Quibel E, Zeller B, Saint-André L, Normand M, Chauvat M, Aubert M. 2018. Soil fauna as bioindicators of organic matter export in temperate forests. For Ecol Manag 429: 549-557. DOI: 10.1016/j.foreco.2018.07.053.
Elsa T, Berthet ET, Bretagnolle V, Lavorel S, Sabatier R, Tichit M, Segrestin B. 2019. Applying ecological knowledge to the innovative design of sustainable agroecosystems. J Appl Ecol 56 (1): 44-51 DOI: 10.1111/1365-2664.13173
Greene AD, Reay-Jones FPF, Kirk KR, Peoples BK, Greene JK. 2021. Spatial associations of key lepidopteran pest s with defoliation, NDVI, and plant height in soybean. Environ Entomol 50 (6): 1378-1392. DOI: 10.1093/ee/nvab098.
Gill HK, Garg H. 2014. Pesticides: Environmental impacts and management strategies. In: Larramendy ML, Solonesk S (eds). Pesticides-Toxic Aspects. InTech Janeza Trdine 9, Rijeka, Croatia.
Hasan N, Suryani E, Hendrawan R. 2015. Analysis of soybean production and demand to develop strategic policy of food self-sufficiency: A system dynamics framework. Proc Comput Sci 72: 605-612. DOI: 10.1016/j.procs.2015.12.169.
Hasibuan R, Lumbanraja J. 2012. The impact of intercropping system and soil fertility management on aphids *Aphis glycines* (Homoptera: Aphididae) populations on soybean plants. Jurnal Hama dan Penyakit Tropika 12 (1): 23-35. DOI: 10.23960/j.hptt.11223-35.
Hanif KI, Herlinda S, Irsan C, Pujiastuti Y. 2020. The impact of bioinsecticide overdoses of *Beauveria bassiana* on species diversity and abundance of not-targeted arthropods in South Sumatra Indonesia freshwater swamp paddy. Biodiversitas 21 (5): 2124-2136. DOI: 10.13057/biodiv/d210541.
Harsono A, Harnowo D, Ginting E, Anggraeni DA. 2021. Soybean in Indonesia: Current status, challenges and opportunities to achieve self-sufficiency. In Carlos DJ, Clemente DA (eds). Legumes. IntechOpen. London.
Herlinda S, Tricahyati T, Irsan C, Karenina T, Hasbi, Suparman, Lakitan B, Anggraini E, Arsi. 2021 Arboreal arthropod assemblages in chili pepper with different mulches and pest managements in freshwater swamps of South Sumatra, Indonesia. Biodiversitas 22 (6): 3065-3074. DOI: 10.13057/biodiv/d220608.
Hodgson EW, McCornack BP, Tilmon K, Knodel JJ. 2012. Management recommendations for soybean aphid (Hemiptera: Aphididae) in the United States. J Integr Pest Manag 3 (1): E1-E10. DOI: 10.1603/IPM11019
Jia H, Liu L, Sun Y, Cai D, Hu J, Ren N, Li Y. 2012. Endosulfan in the Chinese environment: Monitoring and modelling. Front Environ Sci Engineer 6 (1): 32-44. DOI: 10.1007/s11783-011-0375-6.
Karenina T, Herlinda S, Irsan C, Pujiastuti Y. 2019. Abundance and species diversity of predatory arthropods inhabiting rice of refuge habitats and synthetic insecticide application in freshwater swamps in South Sumatra, Indonesia. Biodiversitas 20 (8): 2375-2387. DOI: 10.13057/biodiv/d200836.
Lestari SAD, Sutrisno, Kuntyastuti H. 2017. Short Communication: Effect of organic and inorganic fertilizers application on the early-medium maturing soybean yield. Nusantara Biosci 10 (1): 1-5. DOI: 10.13057/nusbiosci/n100101.
Magdoff F, van Es H. 2021. Building Soils for Better Crops: Ecological Management for Healthy Soils. 4th ed. Sustainable Agriculture Research and Education (SARE) Program, USA.
Magurran AE. 2004. Measuring Biological Diversity. Blackwell Science Ltd, New York.
Majidpour M, Maroofpour N, Ghane-jahromi M, Guedes RNC. 2020. Thiacloprid + deltamethrin on the life-table parameters of the cotton aphid, *Aphis gossypii* (Hemiptera: Aphididae), and the parasitoid, *Aphidius flaviventris* (Hymenoptera: Aphelinidae). Ecotoxicology 113: 2723-2731. DOI: 10.1093/jee/toaa214.
Mattson WJ. 2012. The Role of Arthropods in Forest Ecosystems. Springer-Verlag, Nederland.
Meithasari D, Diptaningsari D, Hariyanto B. 2014. Keanekaragaman serangga hama dan musuh alami pada pertanaman kedelai di Kebun Percobaan Natar dan Tegineneng. Prosiding Seminar Nasional Pengembangan Teknologi Pertanian Politeknik Negeri Lampung. Lampung, 24 Mei 2014. [Indonesian]
Parry HR, Macfadyen S, Hopkinson JE, Bianchi FJJA, Zalucki MP, Bourne A. 2015. Plant composition modulates arthropod pest and predator abundance: evidence for culling exotics and planting natives. Basic Appl Ecol 16: 531-543. DOI: 10.1016/j.baae.2015.05.005.
Prabawati G, Herlinda S, Pujiastuti Y. 2019. The abundance of canopy arthropods in South Sumatra (Indonesia) freshwater swamp main and ratooned rice applied with bioinsecticides and synthetic insecticide. Biodiversitas 20 (10): 2921-2930. DOI: 10.13057/biodiv/d201021.
Quarcoo F, Bonsi C, Tackie N. 2014. Pesticides, the environment, and human health. In: Larramendy ML, Soloneski S (eds). Pesticides - Toxic Aspects. InTech Janeza Trdine 9, Rijeka, Croatia.
Pope TW, Girling RD, Staley JT, Trigodet B, Wright DJ, Leather SR. 2011. Effects of organic and conventional fertilizer treatments on host selection by the aphid parasitoid *Diaeretiella rapae*. J Appl Entomol 136: 445-455. DOI: 10.1111/j.1439-0418.2011.01667.x.
Redlich LS, Emily A. Martin, Ingolf SD. 2019. Landscape-level crop diversity benefits biological pest control. J Appl Ecol 55 (5): 2419-2428. DOI: 10.1111/1365-2664.13126.
Riggi LGA, Bommarco R. 2019. Subsidy type and quality determine direction and strength of trophic cascades in arthropod food webs in agroecosystems. J Appl Ecol 56 (8): 1982-1991. DOI: 10.1111/1365-2664.13444.
Rhodes SA, Turnbull MW, Chong J. 2019, Nitrogen fertilization of host plant influenced the nutritional status and life history of the madeira mealybug (Hemiptera: Pseudococcidae). Environ Entomol 48 (5): 1129-1137. DOI:10.1093/ee/nvz077.
Thrash BC, Catchot AL, Jeffrey G, Cook D, Musser FR, Irby T, Krutz J. 2021. Effects of soybean plant population on yield loss from defoliation. J Econ Entomol 114 (2): 702-709. DOI: 10.1093/jee/toaa279.
Wagner PM, Abagandura GO, Mamo M, Weissling T, Wingeyer A, Bradshaw JD. 2021. Abundance and diversity of dung beetles (Coleoptera: Scarabaeoidea) as affected by grazing management in the Nebraska sandhills ecosystem. Environ Entomol 50 (1): 222-231 DOI: 10.1093/ee/nvaa130.