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Research Article
Effect of Chemical Insecticides on the Arthropod Diversity in the Agroecosystem of Red Onion Crops

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Abstract

Background and Objectives: The diversity and abundance of arthropods in the local red onion agroecosystem of Central Sulawesi are important aspects in ecosystem resources and preservation. This study aims to analyze the effect of insecticide application on arthropod diversity in the agroecosystem of red onion crops. **Materials and Methods:** It is an experimental study which used 500 m^2 of plot divided into two separated plots. Each plot is 250 m^2 and has 300 m space between the plots. The first plot was intended for abamectin insecticide application and the second plot was intended for no application of insecticides. The observation of diversity and abundance of Arthropods was performed by conducting 5 sampling times. **Results:** There were 7 orders of Arthropods found in the ecosystem of red onion crops without insecticides, which included 29 families and 42 species with a total of 4,412 individuals. In red onion crops with insecticides, there were 8 orders found, which included 22 families and 31 species with a total of 12,078 individuals. The individuals found were Hemiptera, Diptera, coleoptera, hymenoptera, lepidoptera, Arachnida, Orthoptera and heteroptera. The diversity index of red onion croppings area with insecticides was 2.06 and of which without insecticides was 1.28. **Conclusion:** The application of insecticides has an effect on the diversity and abundance of arthropods on red onion crops. The values of diversity index, number of family and species were higher in the red onion ecosystem without the application of insecticide.

Key words: Pest control practices, application of chemical insecticides, arthropod diversity, pest resistance and resurgence, red onion croppings area

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Data Availability: All relevant data are within the paper and its supporting information files.

INTRODUCTION

One of the obstacles faced by farmers in developing the cultivation of red onion in the valley area of Palu is the attack of plant pest organisms (OPT)[1-3]. The effort generally implemented to reduce the loss of yield due to pest attack is the use of insecticides[4-7]. The use of insecticides, especially for synthetic organic insecticides, is very effective to control pests and assist in maintaining the production and quality of agricultural products. However, the intensive application in agricultural activities, including in the cultivation of local red onion crops of Palu, kills not only some pestilent organisms but also natural enemies and other non-target organisms; it also changes the behavior of the natural enemies[5,6,8-12].

Cultivation practices implemented by the farmers are very harmful, where the pest control was performed by using insecticides without considering whether or not the applied insecticides are effective[3-5,13,14]. The way farmers use insecticides tends to be unwise and not environmentally friendly. The average application of insecticides on local red onion crops is 2-3 times every week by using insecticides with active ingredients of Abamectin and Spinoteram[5,15].

The application of insecticides is suspected as one of the causes of ecosystem instability, the shift of ecological balance in an ecosystem due to the killing of some natural enemies. Subsequently, the pest problem becomes more complicated and difficult to manage[6,13,16,17]. Insectide contaminated communities will experience simplification of biotic diversity, damage of energy flow and nutrients in an ecosystem[18-20]. In ecosystem management, bio diversity has an important role as a resource and for the preservation of ecosystems[21]. Diversity and abundance of species are the characteristics a biotic community[22]. Diversity describes many types of organisms in the community, while abundance refers to the number of individuals of each species[23]. Species diversity, trophic level diversity and inter-species interactions should be known in ecosystem management, for example, the role of the species in ecosystems[24-26].

The diversity and role of arthropods in the red onion crops ecosystem need to be carefully identified. This is very important because an attack that occurs in a natural component causes an imbalance. Information on the diversity and abundance of Arthropods becomes the data base in identifying the occurrence of the attack. This study aims to examine the effect of insecticide application on arthropod diversity in the ecosystem of local red onion of Palu.

MATERIALS AND METHODS

Research type: It is an experimental study which used 500 m^2 of plot. Field research in Guntarano Village Tanantovea Subdistrict, Donggala District, Central Sulawesi and Research was conducted to identify arthropods in Pest and Disease Plant Laboratory of Agriculture Faculty of Tadulako University. This study was conducted for 9 months in 2017.

Intervention group: There were 2 intervention groups, namely insecticide treated group and non-insecticide group. Each group used a 250 m^2 plot with 300 m spacing. Each plot was divided into 18 sub plots, each measuring 6 m$\times$1.25 m. The distance in sub plots was 35 cm. The abamectin insecticide treatment was applied once a week with a concentration of 1 mL of formulation per liter of water and a spray volume of 500 L ha^{-1}. The spraying began at the age of 1 MST and ended 7 days before the harvest.

Data collection: The observation on diversity and abundance of Arthropods was conducted for 5 sampling times using various insect traps (swim net, yellow sticky trap, pithfall trap and light trap). The traps were installed and left out for 2 days. The sampling was performed by using systematic quadrant technique by installing 18 sampling points for pithfall trap and 18 points for yellow sticky trap; 1 sampling was conducted by installing the 8-shaped insect net. Each arthropod from each type of traps was separated and labeled according to the observation time and further identification was performed at the Laboratory of Plant Pests and Diseases of the Faculty of Agriculture, Tadulako University.

Identification of arthropods: Identification of arthropods was performed in the laboratory in accordance with the applicable identification rules using the determination key of Borror *et al.* (2005). The identification was also performed by matching insects with gambit and descriptions from several literatures. Arthropod samples were based on their morphological characteristics. The identification was performed until the order, family and genus stages. Furthermore, arthropods were classified based on taxonomy and tropical structure.

Research variables:

- Diversity Index can be calculated using the equation of Shannon-Wienner Index (H')[27]

- Species Richness Index (R) is determined by using the formulation according to Margalef[28]
- Evenness Index (E) is determined by using the formulation according to Piellou[28]
- Dominance Index (D) is determined by using the Simpson's dominance index[28]
- Sorensen's Similarity Index is used for comparing the community structure between the plots by using the following Eq.:

$$\text{Iss (\%)} = \frac{2j}{a+b} \times 100$$

Where:

Iss = Community similarity index
2j = Number of species found on both types of plots
a = Number of species found on the non-insecticide applied plots
b = Number of species found on the insecticide applied plots

Data analysis: Arthropod diversity analysis was conducted using PAST2014 (Paleontological Statistics Software Package For Education) program and the T test was conducted by using MINITAB program.

RESULTS

A higher number of individuals (12,078 individuals) in the insecticide treated red onion crops than in those without insecticide treatment (4,412 individuals) were shown in Table 1.

Composition and abundance of arthropod population according to taxonomy: There are some differences in the number of species, number of individuals and abundance between red onion crops with the insecticides and those without the insecticides (Table 2). The total abundance of arthropods collected from the field of red onion crops treated with the application and without the application of insecticides amounted to 4,412 and 12,078 individuals

Table 1: Total arthropod individuals on red onion crops with and without insecticide application in one cropping season

Order	Family	Species	Role	Without insecticide	With insecticide
Coleoptera	Curculionidae	*Hypomeces squamosus*	Fitofag	23	3
Coleoptera	Chrysomelidae	*Aulacophora* spp.	Fitofag	1	0
Coleoptera	Chrysomelidae	*Phaedonia inclusa*	Fitofag	8	0
Coleoptera	Coccinellidae	*Harmonia octomaculata* F	Predator	58	86
Coleoptera	Coccinellidae	*Micraspis lineata*	Predator	21	15
Coleoptera	Coccinellidae	*Coccinella transversalis* F	Predator	46	6
Coleoptera	Scarabaeidae	Species 1	Fitofag	5	0
Coleoptera	*Staphylinidae*	*Homaeotarsus bicolor*	Predator	182	36
Orthoptera	Acrididae	*Oxya chinensis*	Fitofag	21	24
Orthoptera	Acrididae	*Chlorocris prasina*	Fitofag	3	2
Orthoptera	Acrididae	*Locusta migratoria*	Fitofag	13	7
Hemiptera	-	Species 1	Fitofag	7	510
Diptera	Agromizidae	*Liriomyza chinensis*	Fitofag	341	354
Diptera	Agromizidae	*Liriomyza sativae*	Fitofag	70	1994
Diptera	Dolicopodidae	*Chrysosoma* sp.	Predator	4	134
Diptera	Tipulidae	Species 1	-	7	3
Diptera	Tipulidae	*Cylindrotominae*	-	17	0
Diptera	Calliphoridae	*Lucilia sericata*	-	42	5
Diptera	Muscidae	*Musca domestica*	-	46	83
Diptera	Tabanidae	*Stomoxys calcitrans*	-	795	1049
Diptera	Tachninidae	*Eurysacca* sp.	-	3	0
Diptera	Tephritidae	Species 1	Fitofag	8	0
Hemiptera	Aphididae	Species 1	Fitofag	2073	7630
Hemiptera	Aphididae	Species 2	Fitofag	47	0
Hemiptera	Cicadellidae	Species 1	Fitofag	15	5
Hemiptera	Cicadellidae	*Nephotettix negrovictus*	Fitofag	1	1
Hemiptera	Blattidae	Species 1	-	5	1
Hemiptera	Pyrrhocoridae	*Dysdercus cingulatus*	Fitofag	48	12
Hemiptera	Miridae	*Ligolaris* sp.	Fitofag	62	15
Hymenoptera	Eulophidae	*Hemiptarsinus varicornis*	Parasitoid	133	8
Hymenoptera	Eulophidae	*Neochrysochaeres formosa*	Parasitoid	57	0
Hymenoptera	Formicidae	*Semut merah*	Predator	92	30
Lepidoptera	Papilionidae	*Papilio* sp.	Fitofag	6	5

Table 1: Continued

Order	Family	Species	Role	Without insecticide	With insecticide
Lepidoptera	Pyralidae	*Papilio glaucus*	Fitofag	15	3
Lepidoptera	Pyralidae	*Maruca vitrata*	Fitofag	4	1
Lepidoptera	Pyralidae	*Omiodes indicata*	Fitofag	2	3
Lepidoptera	Noctuidae	*Spodoptera exigua*	Fitofag	26	10
Lepidoptera	Geometridae	*Plusia* sp.	Fitofag	54	42
Arachnidae	Agelenidae	Species 1	Predator	9	0
Arachnidae	Lycosidae	*Pardosa* spp.	Predator	22	1
Arachnidae	Araneidae	Species 1	Predator	2	0
Arachnidae	Salticidae	*Carrhotus barbatus*	Predator	18	0
Total				4,412	12,078

-Insect species which have not been identified for the roles

Table 2: Total species and taxonomy of arthropods in the ecosystems of red onion crops with and without insecticide application in one cropping season

Without insecticide application			With insecticide application		
Order	Number of individuals (n = 4,412)	Number of species	Order	Number of individuals (n = 12,078)	Number of species
Coleoptera	344	8	Coleoptera	146	5
Orthoptera	37	3	Orthoptera	33	3
Diptera	1,333	10	Diptera	4,132	7
Hemiptera	2,258	8	Hemiptera	7,664	7
Hymenoptera	282	3	Hymenoptera	38	2
Lepidoptera	107	6	Lepidoptera	64	6
Araneae	51	4	Araneae	1	1

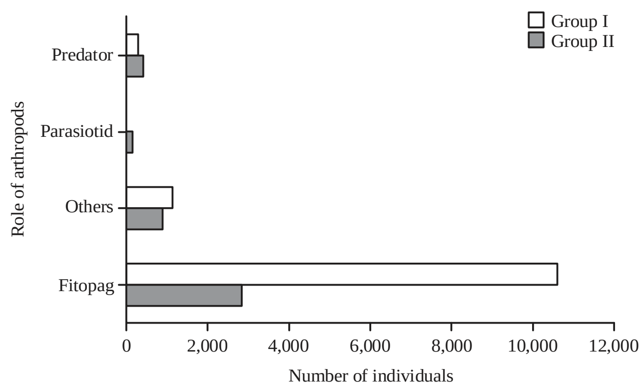

Fig. 1: Composition of arthropods and the roles in each location of observation

respectively. The arthropod composition of onion crops without insecticide application consists of 42 species belonging to 2 classes and 8 orders, while the insecticide applied crops consists of 31 species belonging to 8 orders and 22 families. The majority of arthropod species found from the field of onion crops are the Hemiptera order of 2,258 and 7,664 individuals, respectively).

Composition and abundance of arthropods based on their functional role: Anthropods observation and identification have various roles in the food chain of an ecosystem. Among them are fitofag, predator, parasitoid and other insects. Based on the results of the analysis, there was a difference of Arthropod's role in the location of observation without the application of insecticide as fitofag, other insects, parasitoids and predators. The majority of insect species captured by function play a fitofag insect, then other insects, predators and parasitoids (Fig. 1).

The result of observation on the field of red onion crops without insecticide application showed that the fitofag insect group was the largest group based on its function consisting of coleoptera, orthoptera, heteroptera, diptera, hemiptera and lepidoptera orders, followed by the predator group consisting of coleoptera, diptera, hymenoptera and arachnidae orders. Meanwhile, the observation on the insecticide applied crops showed the largest arthropod group based on its function, which was fitofag for 18 species, followed by the predator group for 7 species (Table 3).

Diversity of arthropods on red onion crops ecosystem: The Shannon-Wiener (H') diversity index values on the red onion crops field were moderate (1.28-2.06) and the species richness index ranged from 3.19-4.86. The evenness index values ranged from 0.12-0.19 (Table 4).

Table 3: Total arthropod species based on order and ecological function in the ecosystem of red onion crops in one cropping period

		Diversity and abundance indices			
Treatment	Order	Fitofag	Predator	Parasitoid	Other insects
Without insecticide application	Coleoptera	4	4	-	-
	Orthoptera	3	-	-	-
	Heteroptera	1	-	-	-
	Diptera	3	2	-	5
	Hemiptera	6	-	-	1
	Hymenoptera	-	1	2	-
	Lepidoptera	6	-	-	-
	Araneae	-	4	-	-
	Total	23	11	2	6
With insecticide application					
	Coleoptera	1	4	-	-
	Orthoptera	3	-	-	-
	Heteroptera	1	-	-	-
	Diptera	2	2	-	3
	Hemiptera	5	-	-	2
	Hymenoptera	-	1	1	-
	Lepidoptera	6	-	-	-
	Araneae	-	1	-	-
	Total	18	7	1	5

Table 4: Values of diversity index, dominance index, evenness index, similarity index and species richness index of arthropods in the ecosystem of red onion crops in one cropping season

Index value	Without insecticide application	With insecticide application
Diversity index (H') (Shannon's index)	2.06	1.28
Dominance index (D)	0.26	0.44
Evenness index		
(Pilou's index) E	0.19	0.12
Species richness index (R) (Margalef's Index)	4.89	3.19
Similarity index (ISS)	0.85	

DISCUSSION

The identification of arthropods based on taxonomy showed that the arthropod species were found to have different roles. The fitofag role was the most commonly found role as many as 23 species compared to the species with natural enemy role, as predators and parasitoids, which work naturally to suppress the population of herbivorous insects. The predator species found were Coleoptera (4 species), Diptera (2 species), Hymenoptera (1 species), Araneae (4 species), while there were 2 species of Hymenoptera Order which played the role of parasitoid. Arthropods play an important role in the structure and process of maintaining the diversity of agricultural ecosystems that play a role in the food web as herbivores, carnivores and detritivores[29,30]. The more the species that make up the community, the more diversified the community will be[8,23]. Predators and parasitoids in onion croplands become actors and constituents of the formation of a community, which can naturally manage the stability of herbivorous insect populations through predation and parasitation activities.

The diversity of arthropods in the experimental field of local red onion of Palu, with and without application of insecticide, showed different species and number of individuals. Based on the results of the observation, the higher number of individuals was found in the red onion crops with insecticides than in those without the insecticides. However, the number of species in the red onion crops without the application of insecticide is higher. This was due to the weekly application of abamectin insecticide.

The use of insecticides is still very effective in controlling pests and very helpful in maintaining the yields and quality. It also kills the arthropod species[17] as characterized by the absence of some arthropod species. However, the intensive application in agricultural activities, including in the cultivation of local red onion crops of Palu, does not only kill some pestilent organisms but also natural enemies and other non-target organisms[5,6,8-10,11,13].

The differences between the treatment and control group caused the number of arthropod species to be higher in the land without the application of insecticides with an evenness value of 0.19 than that in the land without the application of insecticides (0.12). However, in terms of individuals, it has a higher number, specifically for the Hemiptera and Diptera orders. The species richness index ranged from 3.19-4.86, which is in the high category according to Magurran[27]. The high number of species with even species close to 1 resulted in the moderate species richness and diversity values of arthropod in the field of red onion crop experiments without insecticide applications compared to that with insecticide applications. Diversity is identical to the stability of an ecosystem. If the diversity of an ecosystem is high, the condition of the ecosystem tends to be stable[31]. The more species that make up the community, the more diverse the community will be[32]. This will lead to longer food chains and more symbiosis[25]. The types of arthropods in the population will interact with each other, forming food webs. The presence of certain arthropods is strongly influenced by the season and the presence of vegetation. In addition, the population is also influenced by water content, organic matter content and soil temperature[8,24,29].

The species diversity index of the red onion with and without insecticide application, respectively, has a value of >1. i.e., (1.28-2.05). This indicated that species diversity tends to be moderate. The moderate value of diversity in the experimental field without the application of insecticides led to the number of individual species being moderate. This condition results in moderate ecosystem stability[33]. Ecosystem stability is shared by ecosystems that have a moderate to high variety of arthropod species[34], although the condition of the ecosystem is influenced by several factors. One of the most influential factors is the heterogeneity of space which appears to have a dominant effect on the fluctuation of the number of species and individuals both in the field with insecticide application and the field without insecticide application[21].

Low diversity leads to high number of individuals and high diversity leads to low number of individuals. In a balanced ecosystem, there is no organism which stands out compared to other populations[9]. Diversity and abundance are negatively correlated. If diversity is high, the dominance of a species is low[35,36].

This study suggested that the use of insecticides will have implications on the disruption of ecosystem stability, because killing some natural enemies makes them vulnerable to biotic and abiotic stresses compared to natural ecosystems. Pest resistance and resurgence, the decline of natural enemies and other non-targeted bodies and the emergence of new pests are negative impacts of insecticide application and changes in the behavior of natural enemies. The results of this study provide a data base of population density and the role of natural enemies that can be used as a consideration in controlling plant pest organisms (OPT) on the cultivation of red onion variety of Lembah Palu.

The limitation of this research was that the researchers have not been able to find entomopathogen, a biological agent that plays a role in suppressing the development of plant pest organism (OPT) of liriomyza pest.

CONCLUSION

One of the efforts made by the farmers in maintaining the Maintaining the produce of red onion variety of Lembah Palu is by applying the practice of cultivation with the use of insecticides at the age of 1 MST and then applying it in high numbers with the intensity of 2-3 times every week. The practice of pest control with intensive application of chemical insecticides on red onion crops does not only kill pests but also insects that play some roles as natural enemies of predators, parasitoids and other useful insects, thus reducing species diversity.

SIGNIFICANCE STATEMENT

This study reveals that pest control by using chemical insecticides has some implications for ecosystem stability. This study will help the researchers uncover critical areas of pest resistance and resurgence as the decline of natural enemies and other bodies are not subjected to the use of insecticides. Thus, a new theory on the application of insecticides gives rise to new pests with behavior different from that of previous pests.

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