BIODIVERSITAS
Volume 23, Number 7, July 2022
Pages: 3613-3618

ISSN: 1412-033X
E-ISSN: 2085-4722
DOI: 10.13057/biodiv/d230738

Agroecosystem complexity of *Surjan* and *Lembaran* as local farming systems effects on biodiversity of pest insects

DINA WAHYU TRISNAWATI[1,♥], IHSAN NURKOMAR[1], LISA KAWISPA ANANDA[1], DAMAYANTI BUCHORI[2]

[1]Department of Agrotechnology, Faculty of Agriculture, Universitas Muhammadiyah Yogyakarta. Jl. Brawijaya, Kasihan, Bantul 55183, Yogyakarta, Indonesia. Tel./Fax. +62-274-387656, ♥email: dina.trisnawati@fp.umy.ac.id

[2]Biocontrol Laboratory, Department of Plant Protection, Faculty of Agriculture, Institut Pertanian Bogor. Jl. Kamper, Kampus IPB Dramaga, Bogor 16680, West Java, Indonesia

Manuscript received: 7 June 2022. Revision accepted: 25 June 2022.

Abstract. *Trisnawati DW, Nurkomar I, Ananda LK, Buchori D. 2022. Agroecosystem complexity of Surjan and Lembaran as local farming systems effects on biodiversity of pest insects. Biodiversitas 23: 3619-3629.* Farming systems can influence the diversity and abundance of insect pests. This study was conducted to determine the effect of *Surjan* and *Lembaran* farming systems on the diversity and abundance of insect pests in Kulon Progo, Yogyakarta. The field survey was conducted in three *Surjan* paddy fields and three *Lembaran* paddy fields in Panjatan Subdistrict, Kulon Progo Regency. The sampling of pests was collected using four kinds of traps, such as sweeping net, yellow sticky trap, pitfall trap, and yellow pan trap. The traps were set twice in the vegetative phase and twice in the generative phase. The results showed that the abundance of pests in *Surjan* paddy fields was not different from that in *Lembaran* paddy fields. However, the number of pest species in *Surjan* paddy fields was higher than in *Lembaran* paddy fields. In addition, the structure and composition of pests in both farming systems were significantly different. Hemiptera was the most common insect in both farming systems, with dominant pest species of *Nephotettix virescens* and *Nilaparvata lugens*.

Keywords: Abundance, biodiversity, ecosystems, paddy fields

INTRODUCTION

Paddy is the main food crop commodity in Indonesia which is commonly cultivated throughout the year and usually grown in a monoculture, an agricultural system that only cultivates one plant (Lakitan 1995). The balance of the paddy field ecosystem in monocultures is often unstable due to a lack of nutrients (Sakti et al. 2011), low plant diversity, causing an imbalance in the population between pests and their natural enemies such as predators, parasitoids, and pathogens. The development of pest populations in monoculture systems increases continuously because there are no limiting factors from nature such as natural enemies (Tjahjadi 2008). Therefore, a more complex agricultural system is needed to increase the diversity of organisms with diverse roles and functions in the paddy field ecosystem. Complex agroecosystems are considered to make the ecosystem more balanced and stable, because in complex ecosystems, the chances of survival and development of natural enemies are higher so that they can suppress pest attacks (Menalled et al. 1999).

This monoculture paddy field called as *Lembaran* system by people in Kulonprogo, Yogyakarta. Moreover, there is a local farming system called the *Surjan* system where the paddy is planted in a polyculture system with other horticultural crops such as a vegetable plants. The term *Surjan* system is adapted from the morphology of the paddy fields, which, when viewed from above, look striped like *Surjan*, traditional Javanese clothes. The *Surjan* system consists of raised and sunken beds. The sunken beds (lower parts) are planted with paddy, while the raised beds (elevated parts) are planted with horticultural crops (Marwasta and Priyono 2007). This causes the ecosystem of *Surjan* paddy fields to be different from *Lembaran* (monoculture) paddy fields.

The differences in the ecosystem of *Surjan* and *Lembaran* paddy fields may affect the diversity of insect pests as other components in the agroecosystem. This may occur because the composition of plants in *Surjan* paddy fields is more complex than in the *Lembaran* ecosystem, which only consists of paddy. Several studies reported that in complex agroecosystems, pest diversity was higher than in simple agroecosystems. Plećaš et al. (2014) said that pest diversity was found to be higher in complex ecosystems. Van Emden (1991) reported that increasing the diversity of agroecosystems can increase the diversity and abundance of pests. Similar results have also been reported by Yaherwandi et al. (2007) which stated that the diversity and abundance of pests were higher in paddy planted with secondary crops compared to rice grown in monoculture. It is also reported in other ecosystems by Ghazali et al. (2016) that pest diversity was higher in oil palm plantations planted in polyculture due to its more complex ecological characteristics (Harvey et al. 2006). Mamahit (2020) reported that the biodiversity of pest insect on pineapple plantation that applies a cultivation polyculture system is more varied than that in the cultivation monoculture system. Prastowo and Sukarno (2020) also reported that the biodiversity of pest insects in the shallot polyculture system affected the population of pests and natural enemies as well as the level of diversity of pest insects. Complex agroecosystems are also reported to have a higher diversity of natural enemies than simple agroecosystems. For examples Syarief et al. (2017); Amala and Shivalingaswamy (2018); Thomine et al. (2020); Lisdayanti and Nurkomar (2022).

In our previous study, the different configurations of *Surjan* and *Lembaran* paddy fields affect the biodiversity of detritivores, pollinators, and neutral insects (Herdiawan et al. 2021). This generates an interesting question about the diversity of pests in both farming systems and whether the configuration affects the abundance. Since the information on the diversity of pests in *Surjan* and *Lembaran* paddy fields is still limited, this study is aimed to study the diversity of insect pests in both systems.

MATERIALS AND METHODS

Study area

The study was conducted in Panjatan Subdistrict (7° 38'42" - 7° 59'3" S and 110° 1'37" - 110° 16'26" E) Kulon Progo Regency, Special Region of Yogyakarta (Figure 1). Three sites of *Surjan* (S1, S2, S3) and three sites of *Lembaran* (L1, L2, L3) paddy fields with a minimum area of 2000 m^2 for each site were determined intentionally as sampling sites. Each site was divided into three different fields which were defined as the plot for replications. Hence, nine *Surjan* paddy fields and nine *Lembaran* paddy fields were used in this study. *Lembaran* paddy fields (Figure 2a) are planted in a monoculture system. Meanwhile, *Surjan* paddy fields are intercropped with other crops such as melons, spinach, shallots, bananas, cassava, corn, and chilies (Figure 2b). Pesticides such as Antracol, Regent, Trisula, Virtako, and Marshal were used in both paddy fields. In *Surjan* paddy fields, these pesticides were applied three times when the plant was 7, 30, and 50 days old. While the pesticides were applied weekly in *Lembaran* paddy fields. Weeds were controlled manually in *Surjan* paddy fields and controlled chemically using Ricestar herbicide in *Lembaran* paddy fields.

Pest sampling

The study was conducted in April-December 2019. Insect pests sampling was carried out four times, two times when the plant was in vegetative phase (two and four weeks old plant) and two times in generative phase (seven and nine weeks old plant) using four types of traps, i.e., sweeping net, yellow sticky trap (15 x 25 cm), pitfall trap (5 cm in diameter, 5 cm in height), and yellow pan trap (25 x 14 cm) at five sample points which have been determined previously (Figure 3). These traps were selected as a common traps used, cheap, and easy to be installed in the field. The use of sweeping net was carried out by swinging the net ten times of double swing along the direction. Yellow sticky traps were installed diagonally in the opposite direction to the direction of sampling insect pests with sweeping nets. Meanwhile, the yellow pan traps were installed in the middle of the paddy fields. The pitfall traps were installed on the paddy fields to trap ground insects. The last three traps were set for 24 hours. All insect pest sampling activities were carried out in the morning. The captured pests were then taken to the Laboratory of Plant Protection, Universitas Muhammadiyah Yogyakarta for identification.

Insect pest identification

Identification was performed according to the morphological characteristics by grouping insects based on orders, families, and their role as pests and non-pest. The identification was then continued to the species level. Pest identification was carried out by referring to several books such as Borror et al. (1992), Shepard et al. (1987), Kalshoven (1981), and McGavin (2002).

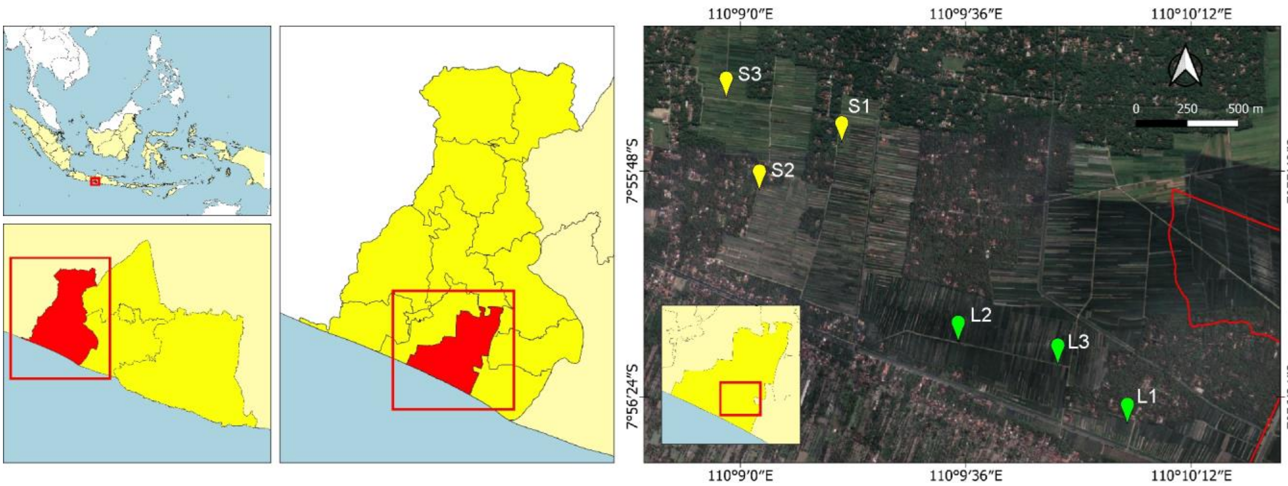

Figure 1. Research site in Kulonprogo, Yogyakarta, Indonesia

Figure 2. Paddy field in Kulonprogo, Yogyakarta, Indonesia. A. *Lembaran* and B. *Surjan*

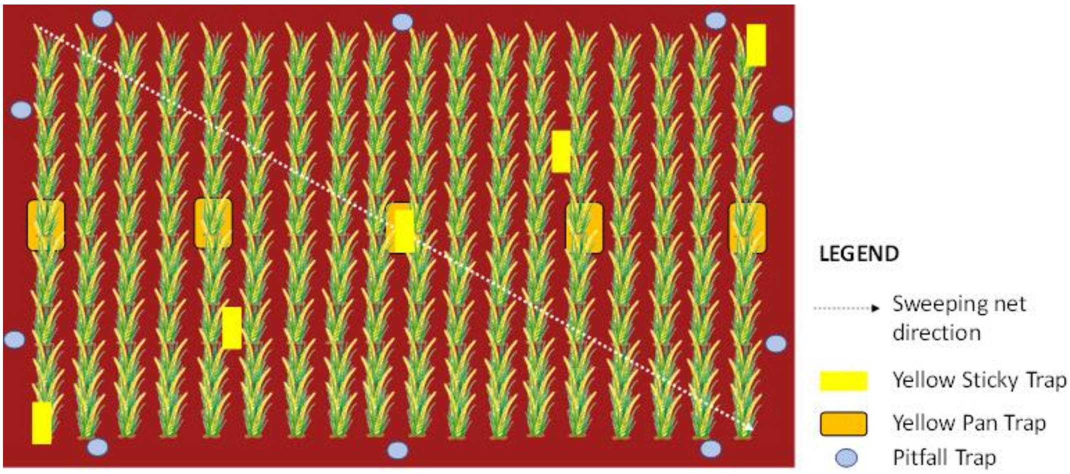

Figure 3. Insect pest sampling method

Data analysis

The data were tabulated into a pivot table using Microsoft Excel 2019. The difference in the number of species and abundance of pests between *Surjan* and *Lembaran* paddy fields were analyzed using paired *t*-test. Alpha diversity analysis was carried out to analyze the diversity of pests in both farming systems using the Shannon-Wiener index (H), Evenness index (E), and Simpson index (D). Meanwhile, beta diversity analysis was performed using the Bray-Curtis index. The Bray-Curtis index is displayed with non-metric multidimensional scaling (NMDS) ordinances to visually describe the differences between the structure and composition of pests in both farming systems. The analysis was carried out using R statistics software (R Core Team 2015) with a vegan package.

RESULTS AND DISCUSSION

The results showed that the number of pest species or species richness of pest was higher in *Surjan* paddy fields than in *Lembaran* paddy fields (Paired t-test, P<0.01) (Figure 4a). There were 78 and 67 pest species found in *Surjan* and *Lembaran* paddy fields, respectively. However, the abundance of pests in both farming systems was relatively the same (Paired t-test, P=0.937) (Figure 4b). This result contrasts with our previous study in which there was no difference in the species richness of detritivores, pollinators, and neutral insect species in the *Surjan* paddy field, but their abundance was higher in that field (Herdiawan et al. 2021).

The presence of a higher number of pest species in *Surjan* paddy fields may be influenced by various types of plants grown. In *Surjan* paddy fields, paddy was planted with other crops such as melons, spinach, shallots, bananas, cassava, corn, and chilies, while in *Lembaran* field, paddy was planted solely. Environment, food availability, predators, competition, and tolerance range of a particular species are factors that affect insect diversity in an ecosystem (Indriani 2017). The life and development of pests are strongly influenced by the food quality and the amount of food available (Fitriana 2006). Analysis of biodiversity indices showed there was no difference in the biodiversity of pests in both systems. The evenness and the dominance of pest insect species between both types of farming systems were also relatively the same (Figure 5).

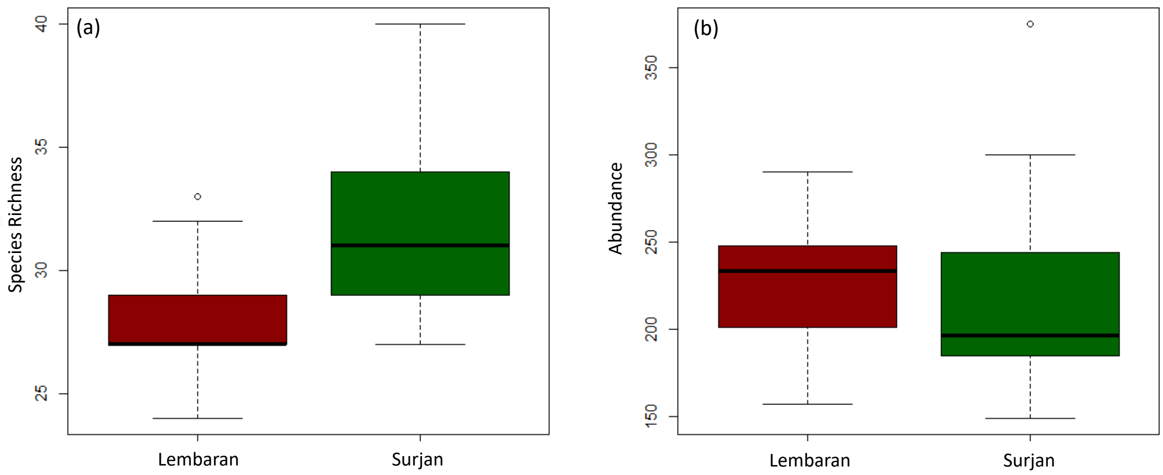

Figure 4. Species richness (A) and abundance (B) of pests in *Surjan* and *Lembaran* paddy fields

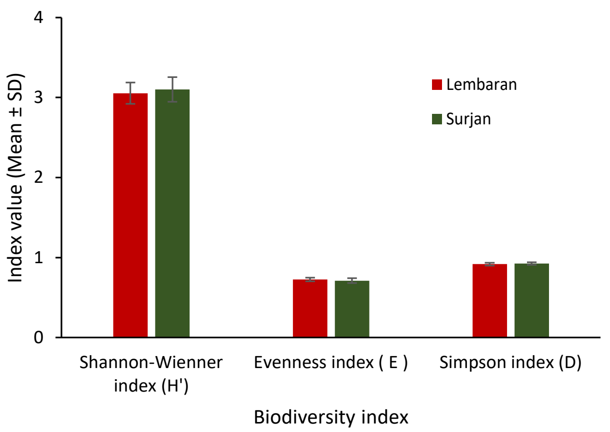

Figure 5. Biodiversity indices of pests in *Surjan* and *Lembaran* paddy fields

In addition to the difference in the number of pest species in *Surjan* and *Lembaran* paddy fields, NMDS analysis showed that the structure and composition of pest species in both farming systems were significantly different (P = 0.1; R_{ANOSIM} 0.5926) (Figure 6). Bianchi et al. (2006) explained that the species composition tends to be high in polyculture farming. However, in an ecosystem, there are often differences in microclimate or environmental conditions that can have an impact on the composition of the insect composition in it (Plećaš et al. 2014). This is because insects follow or adapt to different environmental conditions. The structure and composition of insects in an ecosystem can be related to the richness and/or abundance of insect species in it. In this study, the species richness of pests found in both farming systems was different. Although the abundance of pests found did not differ, the structure and species composition found were also different. This result contrasted with Lizmah et al. (2018) who reported that the abundance, structure, and composition of Hymenoptera insects in complex landscapes are different from those in simple landscapes despite the same number of Hymenoptera insect species found. Nurkomar et al. (2021) also reported the same trend that, in the cassava ecosystem, the number of pest species found between study areas did not differ. However, the abundance, structure, and composition of the pests found in this study between the study areas were very different.

Hemiptera was an order of insects found the most in both *Surjan* and *Lembaran* paddy fields (Figure 7). Hemiptera was the most abundant insect among other insect orders. Nurkomar et al. (2021) also reported that Hemiptera is the most common insect found in the cassava ecosystem. *Nilapavarta lugens* (Hemiptera: Delphacidae), *Nephottetix virescens* (Hemiptera: Cicadellidae), *Aphis gossypii* (Hemiptera: Aphididae), *Cicadula* sp., *Recilia dorsalis* (Hemiptera: Cicadellidae), and *Sogatella furcifera* (Hemiptera: Delphacidae) were species of Hemiptera most found in *Surjan* and *Lembaran* paddy fields (Figure 8).

Nilapavarta lugens and *S. furcifera* are phytophagous cereal plants. Both are the main pests of paddy plants in Asia because they can cause severe damage (Widiarta et al. 2006). These pests suck the sap of the plant stem. The abundances of *N. lugens* and *S. furcifera* were inversely related in the two paddy field systems. A higher number of *N. lugens* was found in *Lembaran* paddy fields, while *S. furcifera* was found more in *Surjan* paddy fields. Kalshoven (1981) said that there are strong indications that in some situations where *N. lugens* has been controlled by resistant plants or pesticide, *S. furcifera* has filled the ecological gap left by the destruction of other pest species. This might have happened in *Surjan* paddy fields because chemical control was applied in this field. *Nilaparvata lugens* was higher in *Lembaran* paddy fields may be because of the present more abundant paddy plant as a food source compared to *Surjan* paddy fields. Yao et al. (2012) said that intercropping of paddy with soybean and corn could decrease the population of *N. lugens*. This is what might cause a lower population of *N. lugens* in *Surjan* paddy fields because of the presence of other plants beside the paddy.

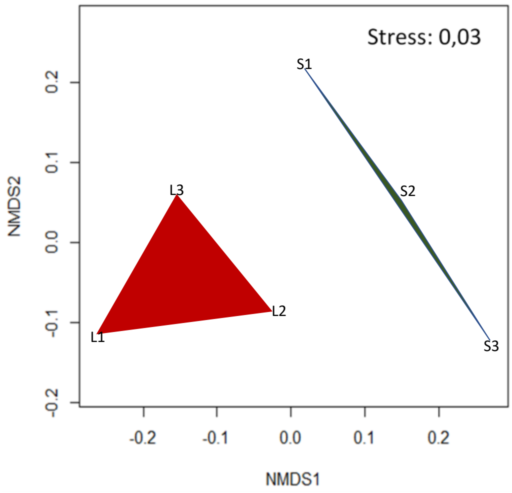

Figure 6. Non-metric multidimensional scaling (NMDS) of pest composition in *Surjan* (S) and *Lembaran* (L) paddy fields. The number shows the study areas

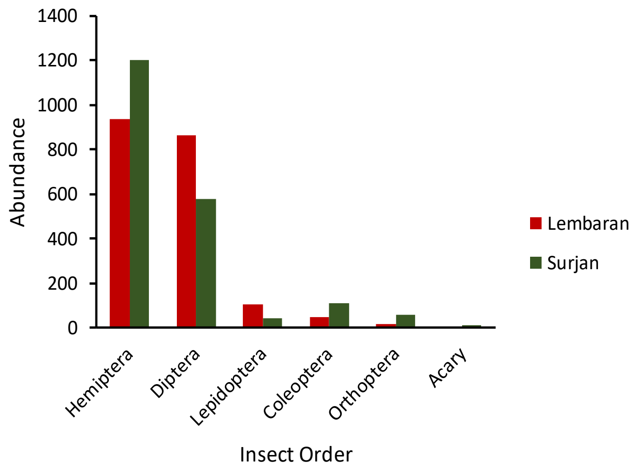

Figure 7. Insect order found in *Lembaran* and *Surjan* paddy fields

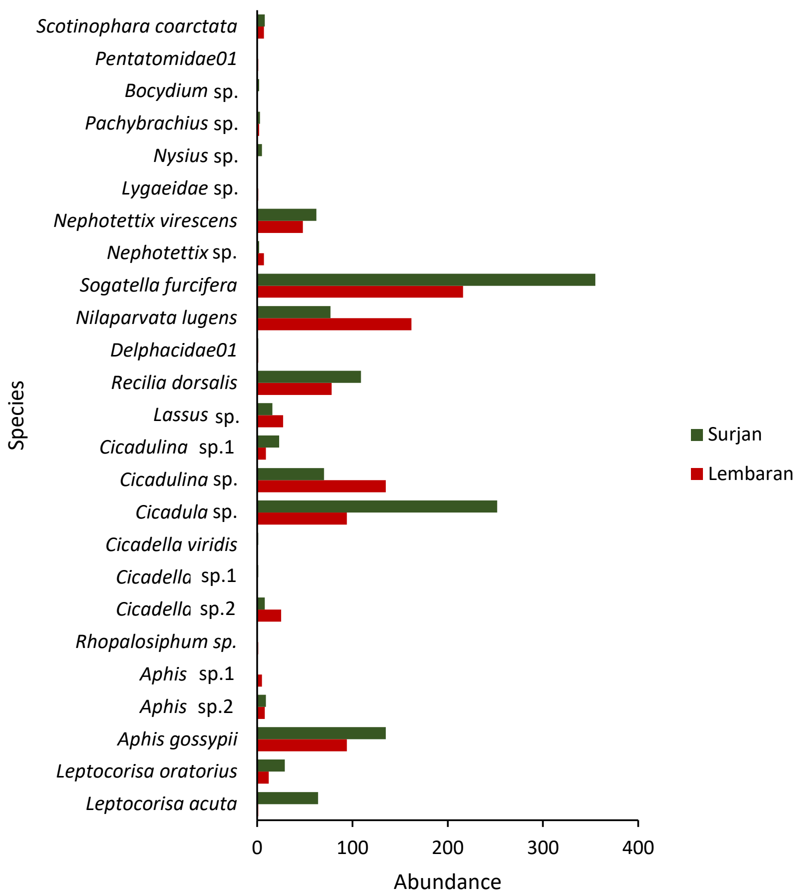

Figure 8. The abundance of Hemiptera species in *Surjan* and *Lembaran* paddy fields

Nephottetix virescens (green planthopper) is also a major pest of paddy. This pest attacks the paddy plant directly by sucking plant fluids and indirectly acts as a tungrovirus vector. The interaction between green leafhoppers, tungrovirus, and paddy will cause tungro disease, which is the most important disease in paddy caused by viruses. This pest is the most important vector because of its highest transmission efficiency, early colonization, and faster population development (Chancellor et al. 1996). Meanwhile, *A. gossypii* is often found on the leaves and stems of host plants. *Aphis gossypii* may have a mutualistic symbiosis with ants because their secretions can produce a liquid containing high sugar (honeydew), while the ants protect the tick from predators and help move places when food reserves are insufficient (Blackman and Eastop 2007). *Cicadula* sp. and *R. dorsalis* belong to Cicadellidae family. This pest family has wings covered with light dust from a waterproof wax material (brochosomes) and harms the plant by sucking the liquid in the plant's body. Some of these species are viral vectors for plants (Dietrich 2005).

The results of this study conclude that planting paddy in a polyculture can increase the species richness of pests and can also reduce their abundance. In other words, planting paddy in polyculture is an effort in managing pest populations at a low population level.

ACKNOWLEDGEMENTS

We thank Fridia Amalia for her valuable comments and English correction. We also thank Ichsan Luqmana Indra Putra from Universitas Ahmad Dahlan, Yogyakarta, Indonesia for the help in insect identification. This study was funded by the Ministry of Research, and Technology/ National Research and Innovation Agency.

REFERENCES

Amala U, Shivalingaswamy TM. 2018. Effect of intercrops and border crops on the diversity of parasitoids and predators in agroecosystem. Egypt J Biol Pest Control 28 (1): 1-4. DOI: 10.1186/s41938-017-0015-y.

Bianchi FJ, Booij CJH, Tscharntke T. 2006. Sustainable pest regulation in agricultural landscapes: a review on landscape composition, biodiversity, and natural pest control. Proc R Soc B: Biol Sci 273 (1595): 1715-1727. DOI: 10.1098/rspb.2006.3530.

Blackman RL, Eastop VF. 2007. Taxonomic issues. Aphids as crop pests. 1: 1-29. DOI: 10.1079/9780851998190.0001.

Borror DJ, DeLong DM 1971. An Introduction to The Study of Insects (No. Ed. 3). Holt, Rinehart & Winston, New York.

Chancellor TCB, Cook AG, Heong KL. 1996. The within-field dynamics of rice tungro disease in relation to the abundance of its major leafhopper vectors. Crop Prot 15 (5): 439-449. DOI: 10.1016/0261-2194(96)00002-6.

Dietrich CH. 2005. Keys to the families of Cicadomorpha and subfamilies and tribes of Cicadellidae (Hemiptera: Auchenorrhyncha). Florida Entomo 88 (4): 502-517. DOI: 10.1653/0015-4040(2005)88[502:KTTFOC]2.0.CO;2.

Fitriana YR. 2006. Keanekaragaman dan kemelimpahan makrozoobentos di hutan mangrove hasil rehabilitasi Taman Hutan Raya Ngurah Rai Bali. Biodiversitas 7 (1): 67-72.

Ghazali A, Asmah S, Syafiq M, Yahya MS, Aziz N, Tan LP, Norhisham AR, Puan CL, Turner EC, Azhar B. 2016. Effects of monoculture and polyculture farming in oil palm smallholdings on terrestrial arthropod diversity. J Asia-Pac Entomol 19 (2): 415-421. DOI: 0.1016/j.aspen.2016.04.016.

Harvey CA, Gonzalez J, Somarriba E. 2006. Dung beetle and terrestrial mammal diversity in forests, indigenous agroforestry systems and plantain monocultures in Talamanca, Costa Rica. Biodivers Conserv 15 (2): 555-585. DOI: 10.1007/s10531-005-2088-2.

Herdiawan WS, Nurkomar I, Trisnawati DW. 2021. Biodiversity of Detritivores, Pollinators, and Neutral Insects on *Surjan* and Conventional Rice Field Ecosystems. In: Muntohar AS, Tsutsumi D, Chung-Yue W, Fujita M, Li A, Trisnawati DW, Yuwono T (eds). Proceeding of the 4th International Conference on Sustainable Innovation 2020-Technology, Engineering and Agriculture (ICoSITEA 2020). Universitas Muhammadiyah Yogyakarta, Yogyakarta, 13-14 October 2020. DOI: 10.2991/aer.k.210204.048.

Indriani P. 2017. Keanekaragaman dan Kelimphan Insekta di Pesisir Pantai Sindangkerta Cipatujah Kabupaten Tasikmalaya. [Hon. Thesis]. Universitas Pasundan, Bandung. [Indonesian]

Kalshoven LGE, Laan VD. 1981. The Pest of Crops in Indonesia. PT. Ichtiar Baru, Jakarta, Indonesia.

Lakitan B. 1995. Fisiologi Pertumbuhan dan Perkembangan Tanaman. Raja Grafinda Persada, Jakarta. [Indonesian]

Lisdayanti H, Nurkomar I. 2022. Diversity of natural enemies in corn-soybean intercropping with different plant compositions. Proceeding of The 4th International Conference on Sustainable Agriculture (ICoSA 2021). Universitas Muhammadiyah Yogyakarta, Yogyakarta, 25-26 August 2021.

Lizmah SF, Buchori, D, Pudjianto, Rizali A. 2018. Kompleksitas lanskap pertanian dan pengaruhnya terhadap keanekaragaman Hymenoptera parasitika. Jurnal Entomologi Indonesia 15 (3): 124-124. DOI: 10.5994/jei.15.3.124. [Indonesian]

Mamahit JME. 2020. Diversity and abundance of insects on pineapple (*Ananas comosus* (L.) Merr.) plantation at Bolaang Mongondow district. Intl J Chemtech Res 13 (2): 62-68. DOI: 10.20902//IJCTR.2019.130208.

Marwasta D, Priyono KD. 2007. Analisis karakteristik desa-desa pesisir di Kabupaten Kulon Progo. Forum Geografi 21 (1): 57-68. DOI: 10.23917/forgeo.v21i1.1819. [Indonesian]

McGavin GC. 2002. Insecta (Sprider, and Other Terrestrial Arthropods). United States by Dorling Kindersley Inc., New York.

Menalled FD, Marino PC, Gage SH, Landis DA. 1999. Does agricultural landscape structure affect parasitism and parasitoid diversity?. Ecol Appl 9 (2): 634-641. DOI: 10.1890/1051-0761(1999)009[0634:DALSAP]2.0.CO;2.

Nurkomar I, Trisnawati DW, Aisyah SN. 2021. Pest insects in cassava plantations intercrop with different plants at Gunungkidul, Yogyakarta, Indonesia. Serangga 26 (1): 1-12. [Indonesian]

Plećaš M, Gagić V, Janković M, Petrović-Obradović O, Kavallieratos NG, Tomanović Ž, Thies C, Tscharntke T, Ćetković A. 2014. Landscape composition and configuration influence cereal aphid-parasitoid-hyperparasitoid interactions and biological control differentially across years. Agric Ecosyst Environ 183: 1-10. DOI: 10.1016/j.agee.2013.10.016.

Prastowo S, Sukarno R. 2020. Manipulation of microhabitat by polyculture planting system as ecosystem stabilizer for management of pests and natural enemies in shallot (*Allium ascalonicum* Linn.). J Trop Ind Agric Rural Dev 1 (1): 33-40. DOI: 10.19184/jtiard.v1i1.16415.

R Core Team. 2015. R: A language and environment for statistical computing. R Foundation for Statistical Computing, Vienna.

Sakti P, Purwanto, Minardi S, Sutopo. 2011. The availability status of macronutrients (N, P, and K) of paddy soil with technical and rainfed irrigation in Karanganyar industrial area, Central Java. Bonorowo Wetlands 1 (1): 8-19. DOI: 10.13057/bonorowo/w010102.

Shepard BM, Barrion AT, Litsinger JA. 1987. Friends of the rice farmer: helpful insects, spiders, and pathogens. International Rice Research Institute, Los Banos, Philippines.

Syarief M, Susilo AW, Himawan T, Abadi AL. 2017. Diversity and abundance of natural enemies of *Helopeltis antonii* in cocoa plantation related with plant pattern and insecticide application. Pelita Perkebunan (a Coffee and Cocoa Research Journal) 33 (2): 128-136. DOI: 10.22302/iccri.jur.pelitaperkebunan.v33i2.266.

Thomine E, Jeavons E, Rusch A, Bearez P, Desneux N. 2020. Effect of crop diversity on predation activity and population dynamics of the mirid predator *Nesidiocoris tenuis*. J Pest Sci 93: 1255-1265. DOI: 10.1007/s10340-020-01222-w.

Tjahjadi C. 2008. Pengantar Teknologi Pangan. Universitas Padjadjaran Press, Bandung. [Indonesian]

Van Emden HF. 1991. Pest Control. Cambridge University Press, UK.

Widiarta IN, Wijay ES, Sawada H. 2006. Dinamika populasi wereng punggung putih, *Sogatella furcifera* Stål (Hemiptera: Delphacidae) di Jawa Tengah. Jurnal Entomologi Indonesia 3 (1): 1-1. DOI: 10.5994/jei.3.1.1. [Indonesian]

Yaherwandi MS, Buchori D, Hidayat P, Budiprasetyo L. 2007. Keanekaragaman komunitas hymenoptera parasitoid pada ekosistem padi. Jurnal HPT Tropika 7 (1): 10-20. DOI: 10.23960/j.hptt.1710-20. [Indonesian]

Yao FL, You MS, Vasseur L, Yang G, Zheng YK. 2012. Polycultural manipulation for better regulation of planthopper populations in irrigated rice-based ecosystems. Crop Prot 34: 104-111. DOI: 10.1016/j.cropro.2011.12.003.