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INSECT BIODIVERSITY IN ORGANIC AND NON-ORGANIC RICE ECOSYSTEM IN THE DISTRICT OF BANTUL

KEANEKARAGAMAN HAYATI SERANGGA PADA EKOSISTEM PADI SAWAH ORGANIK DAN NON-ORGANIK DI KABUPATEN BANTUL

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ABSTRACT

Measuring biodiversity of insects is an essential part in management concept of insect pest populations based on ecology. This study examined the index of insect biodiversity by measuring species richness, species evenness and heterogeneity in organic and non-organic rice farming ecosystem. The sampling was conducted during the planting season of April–May 2015 and October–November 2015 at 44, 52 and 66 days after rice transplanting (DAT). High number of species richness (7 to 13 species) was found in the non-organic rice field (April–May 2015). In contrast, high number of species richness (22 to 33 species) was found in the organic rice field (October–November 2015). The species evenness and heterogeneity in the organic farming were generally higher than these in the non-organic rice in the both of planting season April–May 2015 and October–November 2015. Overall, the organic rice farming ecosystem can increase species richness, species evenness and heterogeneity of insect.

Keywords: insect diversity index, organic and non-organic rice field, rice ecosystem

INTISARI

*Mengukur biodiversitas serangga adalah salah satu bagian penting dalam konsep pengelolaan populasi serangga hama berbasis ekologi. Penelitian ini mengkaji indeks biodiversitas serangga dengan mengukur kekayaan spesies (*species richness*), kemerataan spesies (*species evenness*), dan keanekaragaman/kelimpahan spesies (*heterogenity*) pada sistem budidaya padi organik dan non-organik. Pengambilan sampel diperoleh pada saat musim tanam April–Mei 2015 dan musim tanam Oktober–November 2015 di 44, 52, dan 66 hari setelah tanam. Total kekayaan spesies tertinggi (7–13 spesies) ditemukan di lahan padi non-organik (April–Mei 2015). Sebaliknya, total kekayaan spesies (22–33 spesies) ditemukan di lahan padi organik (Oktober–November 2015). Kemerataan spesies dan heterogenitas di lahan padi organik secara umum lebih tinggi dibanding di padi non-organik pada kedua musim tanam April–Mei 2015 dan Oktober–November 2015. Secara keseluruhan, sistem budidaya di ekosistem padi organik dapat meningkatkan kekayaan spesies, kemerataan spesies, dan heterogenitas serangga.*

Kata kunci: ekosistem padi, indeks biodiversitas serangga, padi organik dan non-organik

INTRODUCTION

Rice farming ecosystem is one of the unstable ecosystems because there were rapid and ever changing conditions in rice farmers cultivation. For example, rice cultivation system using conventional methods causes low biodiversity (Loreau *et al*., 2002). While, organic farming used more environmentally friendly materials for fertilizers and pesticides, which can reduce the leaching of nutrients, store more carbon (Drinkwater *et al*., 1995) and reduce pesticide in the irrigation system. Organic farming is reported to increase the population of natural enemies, such as carabid beetles (Pfinner *et al*., 1996).

Insect is one of the components of agricultural ecosystems which play an important role as herbivores, pollinators, predators and parasitoids. Changes in the abundance and diversity of these insects could potentially alter the ecosystem services (Hillstrom *et al*., 2008). Herbivorous insects in the rice field tend to be more dominant than the non-herbivore guild (Settle *et al*, 1996). However, herbivorous insects live together with other insects (predators, parasitoids, and decomposers, pollinators), which can control the population of herbivorous insects (Untung, 2006; Foottit *et al*., 2009). Insect biodiversity is one of the important information in insect management concept based on ecology (SARE, 2012).

Biodiversity or biological diversity is defined as the number and variety of species or other taxa present in a location, ecosystems, or biosphere region (Price *et al*., 2011). As a system of cultivation, giving a preferred treatment to ascertain the biodiversity that will affect populations of insects (herbivores, predators, parasitoids, and detrivors, pollinators). Some studies showed that organic farming system has able to suppress the growth rate of the abundance of herbivores and carnivores keep groups of arthropods (Padmavathi *et al.*, 2007; Mukerji, 2009). David *et al.* (2005) reported that organic rice cultivation systems can suppress thrips abundance. While several studies have reported that conventional rice system that adds a lot of synthetic inputs would trigger an explosion of insect pests (Hepperly *et al.*, 2009), for example increment the abundance of *Nilaparvata lugens* (Ravi *et al*., 2007).

Index biodiversity is generally measured by including the approach of species richness, evenness, and heterogeneity. Species richness has the number of species in a community or a region (McIntosh,1967). Species evenness is trying to measure the unequal representation of the hypothesis community where all species are generally the same (Lloyd & Ghelardi, 1964). Heterogeneity measure the incorporation of species richness and abundance in the diversity index (Good, 1953) and for the ecological, this concept is the same as diversity (Hurlbert, 1971). There are many formulation to measure the biodiversity index and there interpretation of the index value (Magurran, 1988; Krebs, 1999; Magurran, 2004).

The aims of this study was to examine the index of insect biodiversity by measuring species richness, evenness, and heterogeneity. To address the aim, we conducted a field study in an organic and non-organic rice farming ecosystem was conducted during the planting season April−May 2015 and October−November 2015.

MATERIALS AND METHODS

Location and Time Sampling

Insect samples were collected from rice ecosystem in The Village of Kebonagung, the District of Bantul (6.9932° S, 110.7003° E) to determine the effect of different management of rice cultivation (organic vs. non-organic) on biodiversity of insects. Observation time lasted for two planting seasons, April−May 2015 by using rice varieties Mentik Wangi, and planting season October−November 2015 by using rice varieties Inpari 23. Rice cultivation with organic systems had begun in 2008, and has a certificate from the Institute of Organic Agricultural Production Quality Certification Persada, Yogyakarta. Management of organic and non-organic rice ecosystem difference used of fertilizers, pesticide and plant refuge (Table 1).

Method of Sampling

Insect samples were collected using a modified *D-Vac Vacuum* (IL-130 with rated voltage AC 220−240V and rated frequency 50Hz) at 44, 52, and 66 days after transplanting (DAT). In each sampling time, 40 different hills of rice plants were taken randomly in the organic and non-organic field. The insect samples were identified in the laboratory until the species and they were classified according to the insect's trophic level.

Measure the Biodiversity of Insects

Measuring the spesies richness, species evenness and heterogeneity of the insect samples was conducted to determine the insect biodiversity. Species richness was determined by counting the number of many species of insects found in each plot observations. Species evenness was measured using the Shannon-Wiener index, species evenness interpretation value ranges from 0 to 1 (Magurran, 2004; Krebs, 2009). Heterogeneity measured by Simpson index (D) (Simpson, 1949); the interpretation of Simpson index values range from 0 to 1; zero was the lowest and one was the highest value of diversity (Krebs, 1999; Krebs, 2008).

RESULTS AND DISCCUSSION

Composition of the Number of Individual Insects

The composition of the abundance of individual insect herbivores were found to be higher than the carnivores (predators and parasitoids) in non-organic rice fields and otherwise in organic rice fields in both of planting seasons (April−May 2015 and October−November 2015) (Figure 1 and 2). In April−May 2015, the composition of individual insects in organic rice were: 79% predators (dominated by *Micraspis frenata*), detrivores insects (2%) and pollinators (19%) (Figure 1A). Meanwhile, insects composition in non-organic rice field were: 81% herbivorous insects (dominated by *Nilaparvata lugens*), not found (0%) insect parasitoids and pollinators, detrivores (2%), and predators (19%) (Figure 1B). In the planting season October−November 2015, the composition of organic rice field were: 50% predators (dominated by *Paederus fuscipes* and *Micraspis frenata*), 14% parasitoids (dominated *Oligosita* sp.), 1% pollinators (*Eristalis* sp., *Xylocopa* sp., and *Sphaerophoria* sp.) (Figure 2A). In non-organic field, insects composition were: 62% herbivorous insect (dominated by *Chirothrips* sp. and *Aulacophora* sp.), and no parasitoids and pollinators (Figure 2B).

Species Richness

Non-organic rice ecosystem had the higher value of species richness during the planting season April−May 2015, on rice variety Mentik Wangi (Figure 3A). From the total of 13 species, 12 of them were herbivores (*Nilaparvata lugens*, *Nezara viridula*,

Table 1. Management of organic and non-organic rice ecosystem in Village of Kebonagung, the District of Bantul during in the planting season April–May 2015 used rice variety Mentik Wangi and October–November 2015 used rice variety Inpari 23

Planting system	Organic	Non-organic
Fertilizer	Farmers used compost (7.5 ton/ha) applied at two days before transplanting and 15, 30, 40, 50, and 60 days after transplanting	Farmers used chemical fertilizers (NPK Phonska) at 10 (120 kg/ha), 21 (120 kg/ha), and 40 days after transplanting (50kg/ha)
Pest control	Farmers used *Bacillus subtilis* as biological control agents and applied during seedling.	Farmers used a pesticide (Providor 30 WP) at 50 days after transplanting
Planting flowering plants	Flower plant as refuge was planted in the rainy season	Absent

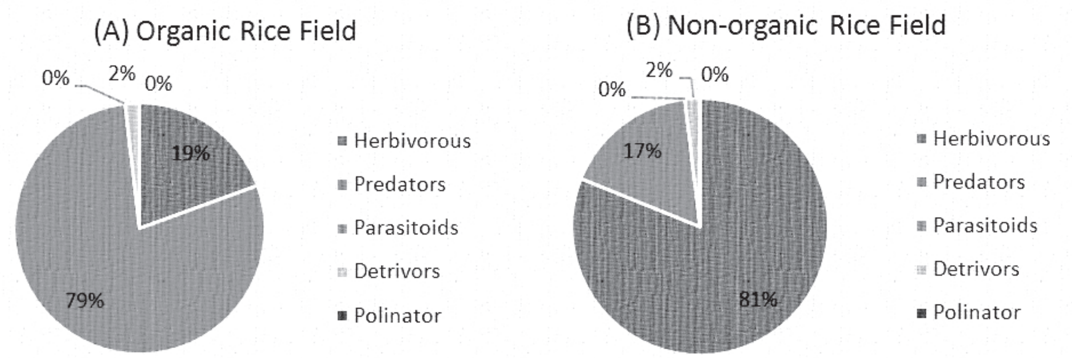

Figure 1. The composition of the individual number of insects during the planting season April–May 2015; in organic rice fields, 79% predators dominated by *Micraspis frenata*, not found (0%) insects parasitoid and pollinators, 2% detrivors and 19% herbivorous (A); in non-organic rice fields, 81% of insect herbivores dominated by *Nilaparvata lugens*, not found (0%) insects parasitoid and pollinators, 2% detrivors and 17% predators (B)

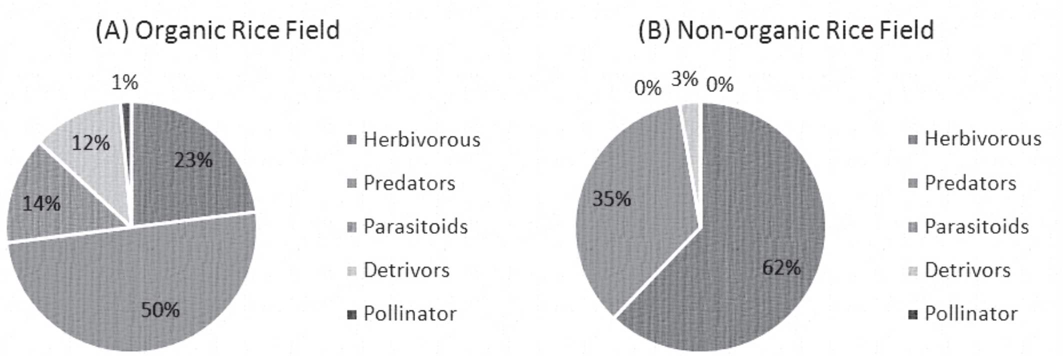

Figure 2. The composition of the individual number of insects during the planting season October–November 2015; in organic rice fields, 50% predators dominated by *Paederus fuscipes* and *Micraspis frenata*, 14% parasitoids (dominated by *Oligosita* sp.), 1% pollinator (*Eristalis* sp., *Xylocopa* sp., and *Sphaerophoria* sp.), 12% detrivors and 23% herbivorous insect (A); in non-organic rice fields, 62% herbivora (dominated by *Chirothrips* sp. and *Aulacophora* sp.), not found (0%) parasitoids and pollinator, 3% detrivors and 35% predators (B)

Sogatella furcifera) while the other 1 species was a predator *Micraspis frenata*. The species richness in organic rice ecosystem was low in the planting season April−May 2015, we found only 3 species of herbivores insect and 4 species of predators. In contrast, in the organic rice field we found 22 to 33 insects species during the planting season October−November 2015 (Figure 3B). In contrary, in the non-organic rice field planting season October−November 2015 we only found 10−15 species, consisting of herbivores, predators and detrivores.

Species Evenness

The species evenness in the organic rice ecosystem was higher than that of in the non-organic rice ecosystem in both planting seasons (Table 2). The highest value (0.9 to 1) of insect species evenness in the organic rice field at 66 DAT and low value (0 to 0.5) in the non-organic rice field at 52 DAT October −November 2015. The number of arthropod found in organic plots were 33 species comprising of 54% predators, 9% parasitoids, 13% detrivores, 2% pollinator, and 21% insect herbivores. The number of individuals in the non-organic rice field at 52 DAT during the planting season October−November 2015 was 113, but most of the individuals were *Chirothrips* sp. as herbivore insects with a few *Paederus fuscipes*, *Micraspis frenata, Polyrachis* sp. as predators, and no parasitoid.

Heterogeneity

The insect diversity in organic rice field was consistently higher than that in non-organic field in both seasons (Table 3). The highest value (0.9) of Simpson's index of insect occurred in the organic rice field during the planting season October−November 2015 and low value (0 to 0.5) occurred in the non-organic rice field during the planting season October−November 2015. The medium value (>0.5 to 0.8) occurred in the organic and non-organic rice field during the planting season April−May 2015 (Table 3). The number of species richness and distribution abundance of individual insect was in balance in the organic rice field during the planting season October−November 2015. However, in the non-organic rice field was dominance by *Chirothrips* sp. as a herbivorous insects (73%) during the planting season October−November 2015.

The abundance of insect herbivores were higher than the carnivores (predators and parasitoids) in non-organic fields, and otherwise in organic rice fields both in the both of planting seasons (Figure 1 and 2). Organic farmers used compost as a soil fertility (7.5 ton/ ha) and *Bacillus subtilis* as a pest control biological agent to controlling plant pests (Table 1). Application of organic fertilizer was safe for beneficial organisms than non-organic fertilizers that tend toxic. Birkhofer (2008) reported that organic fertilizers on crops have a positive impact on the activity of generalist predators such as spiders and Carabidae. Thus, the condition of the soil and healthy plants was favorable to the growth rate of carnivorous insects (predators and parasitoids). Moreover, it will also increased the number of species richness in organic fields (Figure 3) as well as the higher index value of species evenness and heterogeneity of Simpson index (Table 2 and 3).

Meanwhile, in the non-organic rice fields, farmers still used chemical fertilizers (NPK Phonska) as well as pesticides (Providor 30 WP) to control pests (Table 1). Heong *et al.* (2007) proved that reduction of pesticide use more than 95% during the year 1994−2007 at IRRI rice fields can increase species richness of natural enemies from 17 to 38. Some studies also reported that the application of pesticides such as deltamethrin may reduce biological potential parasitoids of *Anagrus nilaparvatae* (Meilin, 2012), and abamectin applications led to increased fecundity of *Nilaparvata lugens* (Wisuda, 2014). Application of insecticides on non-organic rice was not favorable for carnivorous insects, and thus can reduce the pressure on the growth rate of insect herbivorous. That's why the composition of herbivorous insects was higher than carnivores (predators and parasitoids) in non-organic field in both of planting seasons. The use of chemical fertilizers and insecticide applications in non-organic field affected the abundance of individuals, which will also have an impact on the value of species richness non-organic rice field (7−13 species) which was higher than on organic field during April−Mei 2015 (Figure 3). The value of species evenness and heterogeneity of Simpson index were also lower in non-organic field at 52 DAT during October−November 2015 (Table 2 and 3).

Figures 1 and 2 also explained that the composition of insects in the planting season April−May 2015 and October−November 2015 was differed. The percentage of the number of individual abundance of herbivorous insects in organic field April−May 2015 was lower than in rainy season (19% vs 23%) and was dominated by *Chirothrips* sp.. Heinrichs (1994) reported that Rice Thrips in northern India began to emerge early at August and peaked at late August to early September. Meanwhile, the percentage abundance of herbivorous insects in non-organic rice field during April−May 2015 was higher than in October−November 2015 (81% vs 62%), which was dominated by *Nilaparvata lugens*. April− May 2015 farmers used local rice varieties (Mentik Wangi) were susceptible to plant pests, but in the planting season October−

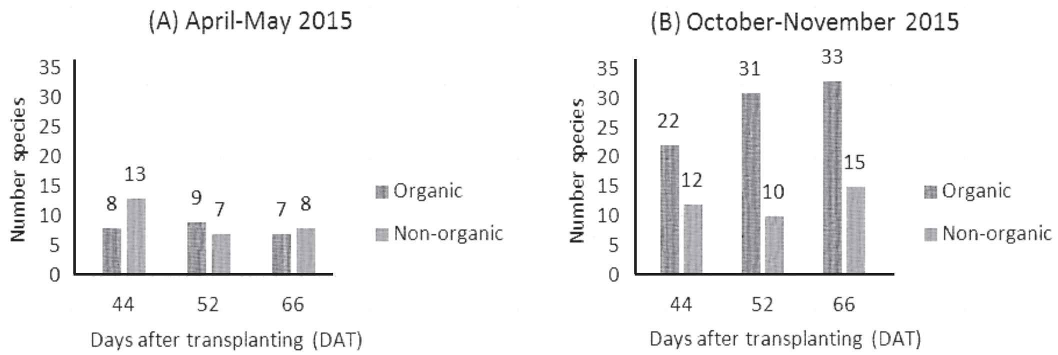

Figure 3. Species richness of insect rice field in the Village of Kebonagung, the district of Bantul: April−May 2015 used rice variety Mentik Wangi (A); October−November 2015 used rice variety Inpari 23 (B)

Table 2. Species evenness of insect in rice ecosystem in the Village of Kebonagung, the District of Bantul during two planting seasons

Sampling Time	Age of rice (DAT)	Evenness	
		Organic	Non-organic
Planting season April−May 2015	44	0.773	0.702
	52	0.865	0.580
	66	0.747	0.634
Planting Season October−November 2015	44	0.858	0.757
	52	0.837	0.458
	66	0.910	0.672

DAT: Days after transplanting
Mentik Wangi rice variety in dry season and Inpari 23 rice variety in rainy season

Table 3. Simpson's Index Diversity (D) of insect in rice ecosystem in the Village of Kebonagung, the District of Bantul

Sampling Time	Age of rice (DAT)	Simpson's Index (D)	
		Organic	Non-organic
Planting season April−May 2015	44	0.746	0.724
	52	0.842	0.529
	66	0.698	0.599
Planting Season October−November 2015	44	0.910	0.799
	52	0.914	0.448
	66	0.952	0.799

DAT: Days after transplanting
Mentik Wangi rice variety in dry season and Inpari 23 rice variety in rainy season

November 2015 farmers used resistant rice varieties (Inpari 23) resistant to *N. lugens* biotypes 1 (BBPTP, 2012). Used of resistant varieties was one way to increase diversity (Lareau *et al*., 2002; Untung, 2006). Meanwhile, the percentage abundance of individual insect carnivore in organic rice field during the planting season April−May 2015 was higher than the planting season October−November 2015 (79% vs 74%) dominated by *Micraspis frenata*. Conversely, the percentage abundance of individual insect carnivore on non-organic rice field during planting season April−May 2015 lower than the planting season October−November 2015 (17% vs 35%) dominated by *Paederus fuscipes*. Presence of insects carnivore in the both of planting season, it is because sufficient available of insects herbivorous in rice fields. *M. frenata* and *Micraspis* sp. were predators of leafhoppers (IRRI, 2011), as well *P. fuscipes* including predators of leafhoppers (*N.lugens*), *Nephotettix virescens* and some other herbivores (Suputa *et al.,* 2015).

The highest species richness (22−33 species) was found in the organic field during October−November

2015 (Figure 3). Besides predators and parasitoids, beneficial insects as pollinators (*Eristalis* sp., *Anthrax* sp., *Sphaerophoria* sp., and *Xylocopa* sp.) was also found in this rice field. Flower plant as refuge was planted by farmers during October–November 2015 (Table 1) and invites the presence of insects. Usyati (2012) reported that the addition of flowering plants in the fields of agro-ecosystem can attract useful insects and suppress pest. Study by Kurniawati (2014) also showed that the flowering plants, sesame (*Sesamum indicum* L.) family Pedaliaceae and *Wedelia* spp. family Asteraceae, increasing the diversity and abundance of arthropods in rice field.

CONCLUSION

Organic rice ecosystems increased the biodiversity of useful insects (predators, parasitoids, pollinators, and decomposers) in both of planting seasons (April–May 2015 and October–November 2015). The higher species richness (22–33 species) was occurred in the organic rice fields during October–November 2015, and during April–May 2015 the highest species richness (7–13 species) was occurred in non-organic rice fields, that dominated by insects herbivorous. The higher of species evenness and heterogeneity of Simpson index,were found in organic rice fields during both of planting seasons. Overall, the organic farming ecosystem increased species richness, species evenness, and heterogeneity of insect.

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LITERATURE CITED

Baudry, J., F. Burel, C. Thenail, & D. Le Coeur. 2000. A Holistic landscape Ecology Study of the Interactions between Activitiesand Ecological Patterns in Brittany, France. *Landscape and Urban Planning* 50: 119–128.

BBPTP (Balai Besar Penelitian Tanaman Padi). 2012. Description Rice Varieties Inpari 23. http://www.litbang.pertanian.go.id, modified 21/3/16.

Birkhofer, K., A. Fliebbach., D.H. Wise & S. Scheu. 2008. Generalist Predators in Organically and Conventionally Managed Grass-Clover Fields: Implications for Conservation Biological Control. *Annual of Applied Biology* 153: 271–280.

Christian, L. & M. Jean-Claude. 2003. *Biodiversity*. John Wiley and Sons Ltd., England. 281 p.

David P.M.M., K. Ezhilrani, & T.M. Thiyagarajan. 2005. Relative Abudance of Insects in SRI and Conventional Rice. *National Symposium on Biodiversity and Insect Pest Management*: 3–4, February 2005. Chennai.

Drinkwater, L.E., D.K. Letourneau, F. Workneh, A.H.C. Van Bruggen, & C. Shennan. 1995. Fundamental Differences between Conventional and Organic Tomato Agroecosystems in California. *Ecological Applications* 5: 1098–1112.

Foottit, R.G. & P.H. Adler (eds.). 2009. *Insect Biodiversity: Science and Society*. Blackwell, Oxford. 623 p.

Good, I.J. 1953. The Population Frequencies of Species and the Estimation of Population Parameters. *Biometrika* 40: 237–264.

Heinrichs, E.A. 1994. *Biology and Management of Rice Insects*. Wiley Eastern Limited. London, U.K. 779 p.

Heong, K.L., A. Manza, J. Catindig, S. Villareal, & T. Jacabsen. 2007. Changes in Pesticide Use and Arthropod Biodiversity in the IRRI Research Farm. *Outlooks in Pest Management* 18: 229–233.

Hepperly P, D. Lotter, C.Z. Ulsh, R. Seidel & C. Reider. 2009. Compost, Manure and Synthetic Fertilizer Influences Crop Yields, Soil Properties, Nitrate Leaching, and Crop Nutrient Content. *Compost Science & Utilization* 17: 117–126.

Hillstrom, M.L. & R.L. Lindroth. 2008. Elevated Atmospheric Carbon dioxide and Ozone Alter Forest Insect Abundance and Community Composition. *Insect Conservation and Diversity* 1: 233–241.

Hurlbert, S.H. 1971. The Non-Concept of Species Diversity: a Critique and Alternative Parameters. *Ecology* 52: 577–586.

IRRI. 2011. *Training on Rice Arthropod Biodiversity and Taxonomy in Thailand*. International Rice Research Institute. Los Baños, Philippines. 147 p.

Klapwijk, M.J., C. Grobler, K. Ward, D. Wheeler, O. Lewis. 2010. Influence of Experimental Warming and Shading on Host-Parasitoid Synchrony. *Global Change Biology* 16: 102–112.

Kurniawati, N. 2014. *Keragaman dan Kelimpahan Musuh Alami Hama pada Habitat Padi yang Dimanipulasi dengan Tumbuhan Berbunga*. Tesis. Fakultas Pertanian UGM, Yogyakarta. 56 p.

Krebs, C.J. 1999. *Ecological Methodology,* 2nd ed. University of British Columbia. 607 p.

Krebs, C.J. 2008. *The Ecological World View*. CSIRO, Australia. 555 p.

Krebs, C.J. 2009. *Ecology: The Experimental Analysis of Distribution and Abundance*. 6th ed. Benjamin Cummings, San Francisco. 689 p.

Lloyd, M. & R.J. Ghelardi. 1964. A Table for Calculating the 'Equitability' Component of Species Diversity. *Journal of Animal Ecology* 33: 217−225.

Loreau, M., S. Naeem, & P. Inchausti. 2002. *Biodiversity and Ecosystem Functioning: Synthesis and Perspectives.* Oxford University Press, New York. 283 p.

Mäder, P., A. Fliessbach, D. Dubois, L. Gunst, P. Fried, & U. Niggli. 2002. Soil Fertility and Biodiversity in Organicfarming. *Science* 296: 1694–1697.

Magurran, A.E. 1988. *Ecological Diversity and its Measurement*. Princeton University Press, New Jersey. 175 p.

Magurran, A.E. 2004. *Measuring Biological Diversity*. Blackwell Publishing, Oxford. 248 p.

Meilin, A. 2012. *Dampak Aplikasi Insektisida pada Parasitoid Telur Wereng Batang Coklat dan Deltametrin Konsentrasi Subletal terhadap* Anagrus nilaparvatae *(Hymenoptera: Mymaridae)*. Disertasi. Fakultas Pertanian UGM, Yogyakarta. 149 p.

Mukerji, R. 2009. *Climate Change: Vulnerability & Adaptation Experiences from Rajasthan & Andra Pradesh: SRI the System of Rice Intensification: Case Study India*. V&A Programme, India.

Mclntosh, R.P. 1967. An Index of Diversity and the Relation of Certain Concepst to Diversity. *Ecology* 48: 392−404.

Padmavathi C.H, R.M. Kumar, L.V. Subba Rao, K. Surekha, P.C. Latha, M.S. Prasad, V.R. Babu & I.C. Pasalu. 2009. Influence of SRI Method of Rice Cultivation on Insect Pest Incidence and Arthropod Diversity. *Oryza* 46: 227−230.

Pfinner, L. & U. Niggli. 1996. Effects of Bio-dynamic, Organic and Conventional Farming on Ground Beetles (Col. Carabidae) and Other Epigaeic Arthropods in Winter Wheat. *Biological Agriculture and Horticulture* 12**:** 353–364.

Price, P.W., R.T. Denno, M.D. Eubank, D.L. Finke, & I. Kaplan. 2011. *Insect Ecology: Behavior, Populations and Communities*. Cambridge University Press, New York. 829 p.

Ravi G, R. Rajendran, N. Raju, K. Chozhan & V. Muralidharan. 2007. *Insect Pest Scenario in Irrigated Rice Grown under SRI Method of Cultivation*. SRI India 2007-II National Symposium on System of Rice Intensification in India-Progress and Prospects. October 3−5, 2007. India.

SARE (Sustainable Agriculture Research & Education). 2012. *How Ecologically Based Pest Management Works*. University of Maryland. http://sare.org, modified 7/3/16.

Schowalter, T.D. 2011. *Insect Ecology: An Ecosystem Approach*, 3rd Edition. Elsevier, London. 625 p.

Settle, W.H., H. Ariawan., E.T. Astuti, W. Cahyana, A.L. Hakim, D. Hindayana, A.S. Lestari, Pajarningsih, & Sartanto. 1996. Managing Tropical Rice Pests through Conservation of Generalist Natural Enemies and Alternative Prey. *Ecology* 77: 1975–1988.

Simpson, E.H. 1949. Measurement of Diversity. *Nature* 163: 688.

Suputa., A.T. Arminudin., Desmawati., W. Puji, A.A. Ma'rufah., R. Warduna, T. Sulistyawati, T.B. Putra. 2015. *Pengenalan Musuh Alami (Predator & Parasitoid) dan Pemanfaatannya*. Direktorat Perlindungan Hortikultura, Jakarta. 170 p.

Untung, K. 2006. *Pengantar Pengendalian Hama Terpadu.* 2nd ed. Gadjah Mada University Press, Yogyakarta. 348 p.

Usyati, N. Kurniawati, N. Baehaki, SE., Triny S.K. 2012. *Pengawalan Tanaman Padi di Dalam dan Sekitar Kebun Sukamandi serta Pengendalian Hama dengan Rekayasa Ekologi*. Laporan Akhir Tahun. ROPP DIPA. Balai Besar Penelitian Tanaman Padi. Badan Penelitian dan Pengembangan Pertanian.

Wisuda, N.L. 2014. *Resurjensi Wereng Batang Coklat akibat Aplikasi Insektisida Abamektin*. Tesis. Fakultas Pertanian Universitas Gadjah Mada, Yogyakarta. 42 p.