PARASITISM OF THE RICE BROWN PLANTHOPPER EGGS IN VARIOUS PERIODS OF TIME OF THE DAY

PARASITASI TELUR WERENG BATANG PADI COKELAT PADA BERBAGAI PERIODE DALAM SATU HARI

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ABSTRACT

The rice brown planthopper, *Nilaparvata lugens* (Hemiptera: Delphacidae) is an important pest of rice. Since at the early stage, this pest is infested by parasitoids, but most cultural practices do not consider the existences of parasitoids in rice ecosystem. This study was aimed to determine the level of parasitism on *N. lugens* with regard to the time of the day. This information would be useful to minimize the effect of insecticide application to the parasitoids. Trapping of egg parasitoids in rice ecosystem was conducted every two hours from 05.00 a.m. until 04.00 p.m. Parasitism occured as early as at 05.00 a.m. (12.26% of the total parasitoid found), reached the peak abundance at 11.00 a.m. (36.13%), and decreased at 01.00 p.m. The parasitism level varied from 1.12 to 8.51% at 66 days after planting. The highest number of parasitoids and the highest parasitism level occured when trapping was conducted between 11.00 a.m.−01.00 p.m.. Before and after this period of time, the number of parasitoid emerged and parasitism were low. This suggest that if insecticide is necessary, it should be applied in the early morning or late afternoon.

Keywords: egg parasitoid, *Nilaparvata lugens,* parasitism

INTISARI

Wereng batang padi cokelat, Nilaparvata lugens *(Hemiptera: Delphacidae), merupakan salah satu hama penting padi. Praktik budidaya pertanian padi belum memperhatikan aktivitas parasitoid dalam ekosistem. Tujuan dari penelitian ini yaitu untuk mengetahui tingkat parasitasi telur* N. lugens *pada beberapa waktu dalam sehari. Informasi ini akan bermanfaat untuk mengurangi dampak aplikasi insektisida terhadap parasitoid. Pemerangkapan parasitoid telur* N. lugens *di lahan padi dilakukan setiap dua jam yang dimulai pada pukul 05.00 sampai pukul 16.00. Parasitoid telur* N. lugens *mulai aktif pada pukul 05.00 (12,26%), mencapai puncaknya pukul 11.00 (36,13%), dan mulai mengalami penurunan pada pukul 13.00. Tingkat parasitasi pada tanaman padi umur 66 hari setelah tanam berkisar mulai 1,12−8,51%. Hasil pemerangkapan menunjukkan bahwa jumlah parasitoid yang paling banyak muncul dan tingkat parasitisme tinggi terjadi pada waktu pemerangkapan yang dilakukan pada pukul 11.00−13.00. Sebelum dan sesudah waktu pemerangkapan tersebut jumlah parasitoid dan tingkat parasitisme rendah. Hal ini menunjukkan bahwa apabila aplikasi insektisida diperlukan, maka harus dilakukan di pagi hari atau sore hari.*

Kata kunci: Nilaparvata lugens*, parasitasi, parasitoid telur*

INTRODUCTION

The rice brown planthopper, *Nilaparvata lugens* Stal. (Hemiptera: Delphacidae) is one of the major insect pests which threaten rice production in Indonesia. Attack by *N. lugens* leads to hopper burn symptom thus causing a serious loss for farmers (Catindig *et al*., 2009). Besides causing crop failure, *N. lugens* has a role as a vector of rice grassy stunt and ragged stunt viruses (Reissig *et al*., 1986). The control of *N. lugens* has relied on the use of conventional insecticides, and its application in the fields often neglect the activity and function of natural enemies. Thus, improper use of insecticides can disrupt the performance of natural enemies in helping to control *N. lugens*. Therefore, the application of insecticides should be suited to minimize the risk to the activity period of natural enemies.

Biological control is an effort to manipulate, utilize, and optimize the function of natural enemies in reducing or repressing pest population to the minimum below the control threshold. Egg parasitoids are effective to control pest population much earlier, i.e. in the egg phase (Godfray, 1994; Untung, 2006). The mymarid wasp is one of the important egg parasitoid of *N. lugens* that is widely spread in Asia, East India, China, Japan in the north, South Malaysia, Singapore, and Vietnam (Gurr *et al*., 2011). In China, there are 424 species of natural enemies of rice pests. In Indonesia, hymenopteran parasitoids of *N. lugens* commonly found in Klaten and Bantul were *Anagrus nilaparvatae* (Mymaridae), *Oligosita* (Trichogrammatidae) and *Gonatocerus* (Mymaridae) (Meilin, 2012; Lou *et al*., 2014).

The time of parasitoid emergence determines the success of parasitation in the field. A parasitoid is an insect with the type of proovigenic reproduction i.e. parasitoid that has mature eggs at early adult stage (Mutitu *et al*., 2013). The light period affects the circadian cycle (c*ircadian rhythm*) which regulates the daily physiological activity, mobility, mating, oviposition, egg hatching, pupation, pupa eclosion, releasing of pheromone, the sensitivity of the retina to light, sensitivity to smell, learning process and memory (Page, 2003). Research in the laboratory showed that *A. nilaparvatae* emerged at 07.00 a.m. and reached its peak at 09.00−10.00 a.m. *Ostrinia furnacalis* laid eggs at 06.00 p.m.−06.00 a.m., and the peak of egg laying occured at 10.00 p.m.–02.00 a.m. (Meilin *et al*., 2012; Budiman, 2014). These previous research suggest that understanding circadian rhythm may be useful for developing management practice of economically important pest, such as *N. lugens.*

Farmers generally spray conventional insecticides in the morning. This habit may disrupts the activity of natural enemies, particularly parasitoids because parasitoids mostly emerged in the morning until noon. There is a need to understand the biological clock of egg parasitoids for *N. lugens* so that control using conventional insecticides, which is the last option of Integrated Pest Management (IPM), has a minimum negative effect on parasitoids. The aim of this research was to determine the times when the parasitoids emerge from *N. lugens* eggs and the parasitism level in the field as the bases for recommendation on the application of insecticides, thus minimum negative impact is expected.

MATERIALS AND METHODS

Mass rearing of Nilaparvata lugens

The research was conducted at laboratory under the temperature of 28.8−28.9°C and relative humidity of 59.9–64.9%. Mass rearing of *N. lugens* employed a laboratory established procedure used since 1985. Cisadane rice seeds were washed, soaked for 24 hours, air-drained and kept for two days to germinate. Those rice seeds were germinated in the jars (diameter of 20 cm and height of 19 cm) covered with white cloth. Three to five days after germination, the rice seeds were used as natural diet and egg laying media. *N. lugens* used in this study was obtained from the adapted laboratory population that has been reared in the laboratory since 1985. The new rice seedling was supplied every week or when the plants became yellow and dry, until the nymphs of *N. lugens* became adults. This rearing method was continued until the population of *N. lugens* sufficient for testing.

Parasitism

The location for egg parasitoids trapping was a rice organic farming field in Kebonagung Village, Imogiri district, Bantul regency, Yogyakarta with altitude of 110°22’16.96", and 60.8 meter above sea-level. Soil pH was 7.25 with organic C-content of 3.48% (personal communication). Thirty hills of Inpari 23 rice variety were collected from the field at the age of 55 days after planting (DAP) and transferred into 30 pots (upper diameter of 23 cm, lower diameter of 16 cm, and height of 16 cm). One week later, those potted plants were covered with a cylindrical plastic tube (diameter of 18 cm and height of 100 cm) and white tulle fabric on top. Fifty adults of *N. lugens* were introduced to lay eggs for three days before field-released. The plants with *N. lugens* eggs (66 DAP) were brought and left in the fields for parasitoids trapping.

Trapping design. Trapping was used to determine the activity of the parasitoids in the *N. lugens* eggs employing Randomized Complete Block Design (RCBD). The trapping plants were placed at various periods to determine the difference in the parasitation level and the number of parasitoids emerged. The trapping (treatments) were divided into six periods at 05.00−07.00 a.m., 07.00−09.00 a.m., 09.00−11.00 a.m., 11.00 a.m.−01.00 p.m., 01.00−04.00 p.m., and 05.00 a.m.−04.00 p.m. Each treatment used five plots as replications. The size of rice plots used for each replicate was 1,000; 1,300; 1,500; 1,500; and 1,200 m^2, respectively.

Observation of temperature, humidity, and light intensity in rice fields. The temperature and relative humidity in the rice plantation, and light intensity were measured every two hours, starting at 06.00, 08.00, 10.00, 12.00 a.m., and 02.00 p.m. Thermohygrometer (Haar Synt. Hygro) was used for observing temperature and relative humidity and lux meter (Luxtron LX-107) was used for observing of light intensity.

The number of parasitoids emerged and the parasitism level. After the potted rice plants were exposed for parasitoid infestation, the plants were taken to the laboratory for observation and identification of parasitoids emerged. The rice stems where the *N. lugens* laid their eggs were cut. The lower part of the rice stems was wrapped with a moist-tissue and transfered into the plastic pots (upper diameter of 9 cm, lower diameter of 6 cm, and height of 12 cm). The stems were covered with a cylinder plastic tube (7 cm in diameter and 50 cm in height with white cloth on the upper part). Observations were conducted daily at three periods (07.00−10.00 a.m., 10.00 a.m.−01.00 p.m., and 01.00−04.00 p.m.) starting at the seventh day after trapping until no more parasitoids emerged. The number and species of parasitoids, and the number of *N. lugens* nymphs emerged were recorded. The parasitism level was calculated by dividing the number of parasitoids collected by the total number of *N. lugens* nymphs, parasitoids found, and unhatched eggs.

Data analysis. Analysis of Variance (Anova) was performed using RCBD employing SAS 9.1.3. Portable. Analysis was continued with DMRT test when significant differences existed. The regression and correlation analysis were used to determine the relationship between temperature, relative humidity and light intensity with the number of parasitoids emerged and the parasitation level.

RESULTS AND DICUSSION

Temperature, relative humidity, and light intensity. The temperature of the rice field at 07.00 a.m. was not different from noon until 04.00 p.m. However, the relative humidity decreased toward the afternoon and increased again during the evening (Table 1). In contrast, the light intensity varied from 18.2×10^6 to 109.10×10^6 flux with the peak at the afternoon.

The number of parasitoids emerged and the parasitism level. The highest number of parasitoids emergence occurred from the trapping at 11.00 a.m. −01.00 p.m. with 56 parasitoids (36.13%) and the lowest was from 01.00−04.00 p.m. with 9 parasitoids (5.81%). The numbers of parasitoids emerged from trapping at 05.00−07.00, 07.00−09.00, 09.00−11.00 a.m. were very similar ranging from 19−23 parasitoids. The parasitism varied from 1.12 to 8.51%, with the peak occurred from trapping at 11.00 a.m.−01.00 p.m. (Figure 1).

Emergence time of parasitoids in the laboratory. Parasitoids collected from the field emerged everyday starting from the seventh until fourteenth day after trapping (Figure 2). In the laboratory, 49.68% of the parasitoids emerged at 07.00−10.00 a.m., and the emergence decreased during the two following periods (10.00 a.m.−01.00 p.m. and 01.00−04.00 p.m.) (Figure 3). The genera of parasitoids found were *Anagrus* and *Oligosita*. *Oligosita* was the dominant genus of parasitoid emerged on first and last day of observation, with 31.46 and 33.71%, respectively. In contrast, the emergence of *Anagrus* was relatively similar from the seventh to thirtheenth day after trapping (7.58−21.21%) (Figure 4).

Effects of micro climate on parasitoids. Temperature, relative humidity, and light intensity in the rice ecosystem varied depending the time of the day. However, those variation didn't affect to the number of parasitoids emerged and the parasitism level of *N. lugens* eggs $R \leq 0.053$(Figure 5).

Parasitoids of *N. lugens* eggs remained plenty when the rice plants aged 66 DAP. Although *N. lugens* eggs were only exposed for two hours the parasitism reached the highest (8.51%) when the egg of *N. lugens* were placed between 11.00 a.m. to 01.00 p.m. The parasitism were lower before and after the peak period. The stage of rice plants in fields affects the abundance of parasitoids. The older rice plants, the smaller the number of parasitoids (Dewi, 2005). However, the egg parasitoids could be found on the rice aged 60-103 DAP (Watanabe *et al*., 1992).

The cultivation practices affect the activity of natural enemies, particularly parasitoids. Garrat *et al*. (2011) stated that the use of organic fertilizer could have a positive effect on the existence of parasitoids. The C-organic content of the soil (3.48%) in Kebonagung Village, Imogiri is characterized as medium to high (3.41–4.79%) (Anonymous, 2015). The organic matter is the source of C element and energy for soil microorganisms. The soil pH determines how much the production of biomass and the

Table 1. The micro climates in the rice ecosystem (66 days after planting) used for trapping of the egg parasitoids of *Nilaparvata lugens* in Kebonagung Village, Imogiri, Bantul

Trapping time	Temperature (°C)	Relative humidity (%)	Light intensity (flux)
05.00−07.00	33,00 ± 3,89	74,20 ± 8,58	$18,20\times10^6$
07.00−09.00	34,10 ± 4,25	72,60 ± 12,18	$39,00\times10^6$
09.00−11.00	35,20 ± 4,09	68,60 ± 12,34	$109,10\times10^6$
11.00−13.00	34,10 ± 3,91	70,20 ± 11,17	$52,00\times10^6$
13.00−16.00	33,80 ± 3,33	70,50 ± 10,42	$85,00\times10^6$
05.00−16.00	34,04 ± 3,73	71,22 ± 10,55	$60,64\times10^6$

Trapping was conducted on November 5, 2015. Thermohygrometer and lux meter were placed in the rice field.

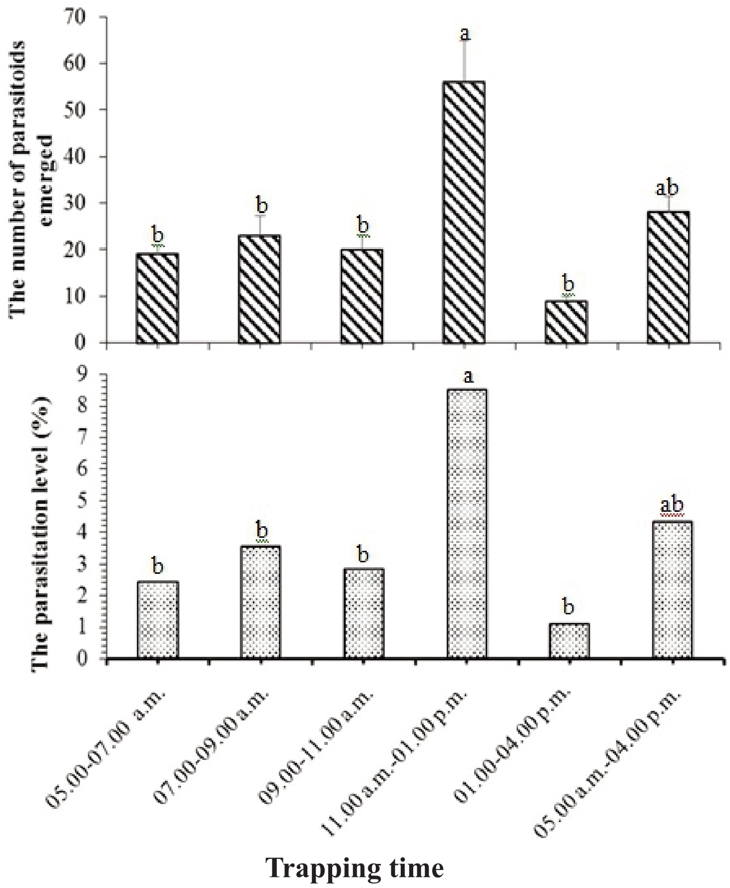

Figure 1. The number of parasitoids emerged and the parasitation level of *Nilaparvata lugens* eggs from trapping at different time of the day; the trapping was conducted in rice variety of Inpari 23 at 66 days old in Kebonagung Village, Imogiri, Bantul; means followed by the same letter are not significantly different, DMRT at α=0.05

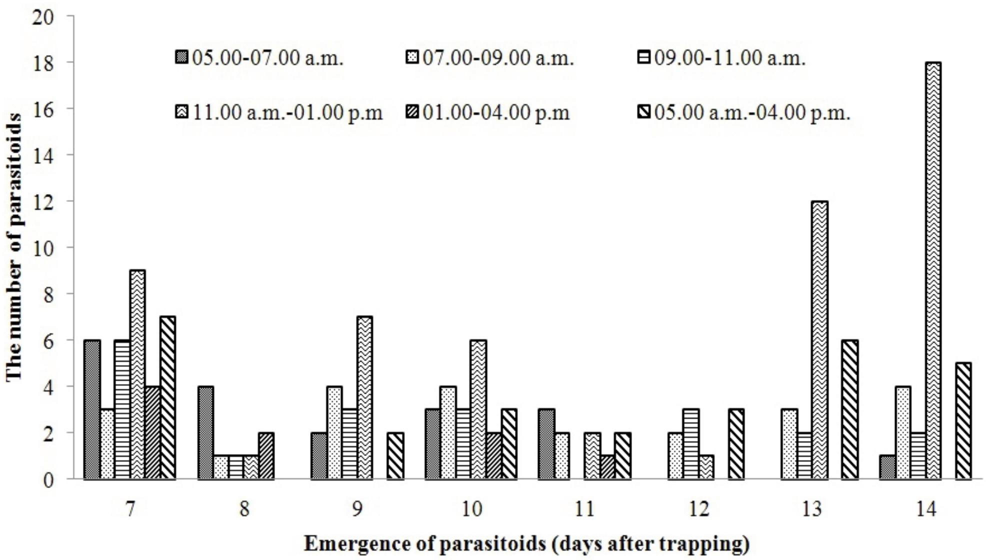

Figure 2. Parasitoids of *Nilaparvata lugens* eggs emerged per day from various trapping times of the day; trapping was conducted in 66 day old rice plantation (Inpari 23) in Kebonagung Village, Imogiri, Bantul

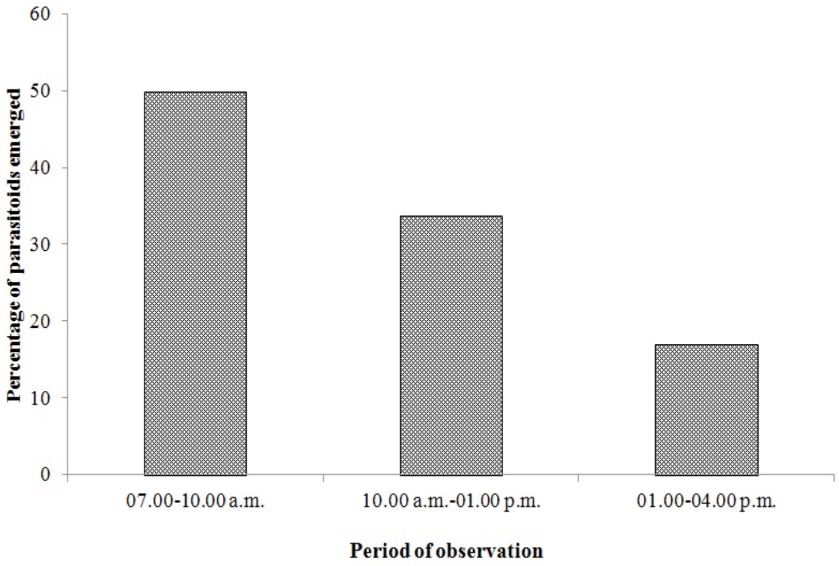

Figure 3. The emergence of egg parasitoids of *Nilaparvata lugens* under laboratory conditions; trapping was conducted in 66 day old rice plantation (Inpari 23) in Kebonagung Village, Imogiri, Bantul

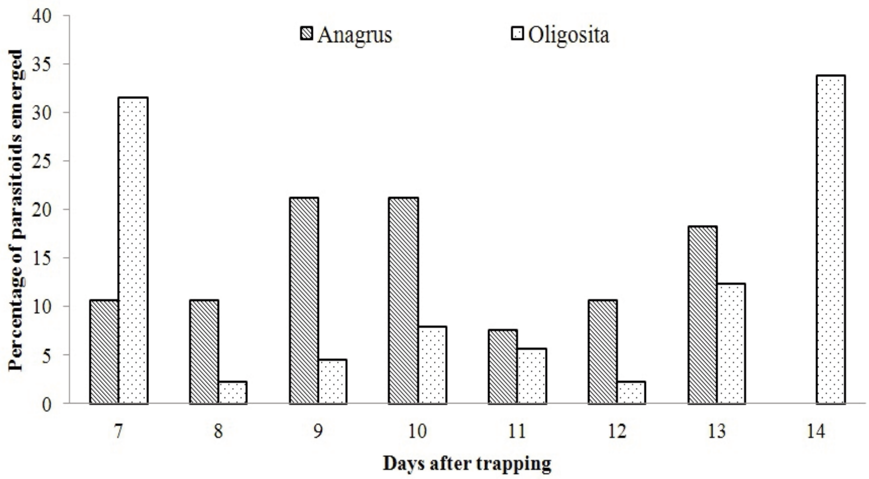

Figure 4. Species of parasitoids emerged from *Nilaparvata lugens* eggs. Trapping was conducted in 66 day old rice plantation (Inpari 23) in Kebonagung Village, Imogiri, Bantul.

activity of soil microorganisms. The acid or alkaline soil reduces the activity of soil microorganisms to decompose organic matters. Soil pH of 7.25 and high contain of C in the location used for trapping provided a good environment of parasitoids.

Furthermore, the use of fertilizer, the pesticide application, different agricultural landscapes, and stages of plants affect the existence of natural enemies (Macfadyan *et al*., 2009; Dewi, 2005). Thomson *et al*. (2010) stated that micro-and macroclimates and availability of hosts could affect the activity and effectiveness of parasitoids. Meilin (2012) reported that the number of parasitoids and the parasitation level in fields with application of conventional pesticides unwisely were lower than those in the organic fields. The absence of hosts and nectar, and egg maturation patterns of the egg parasitoids of *N. lugens* could reduce the parasitation level (Fleury & Bouletreau, 1993; Abdilah, 2015).

The parasitism reached the highest from the trapping time of 11.00 a.m. to 01.00 p.m. because the parasitoids started to parasitize as early as 05.00 a.m. Therefore, the parasitoids activity during the period of 5.00 a.m. to 01.00 p.m. contributed to high parasitism. After 01.00 p.m., the parasitism was the lowest which may be due to the condition of hight temperature, low relative humidity, and high light intensity although each of those parameters did not have any effect individually. Other studies reported that temperature could affect the survival, longevity, and fecundity

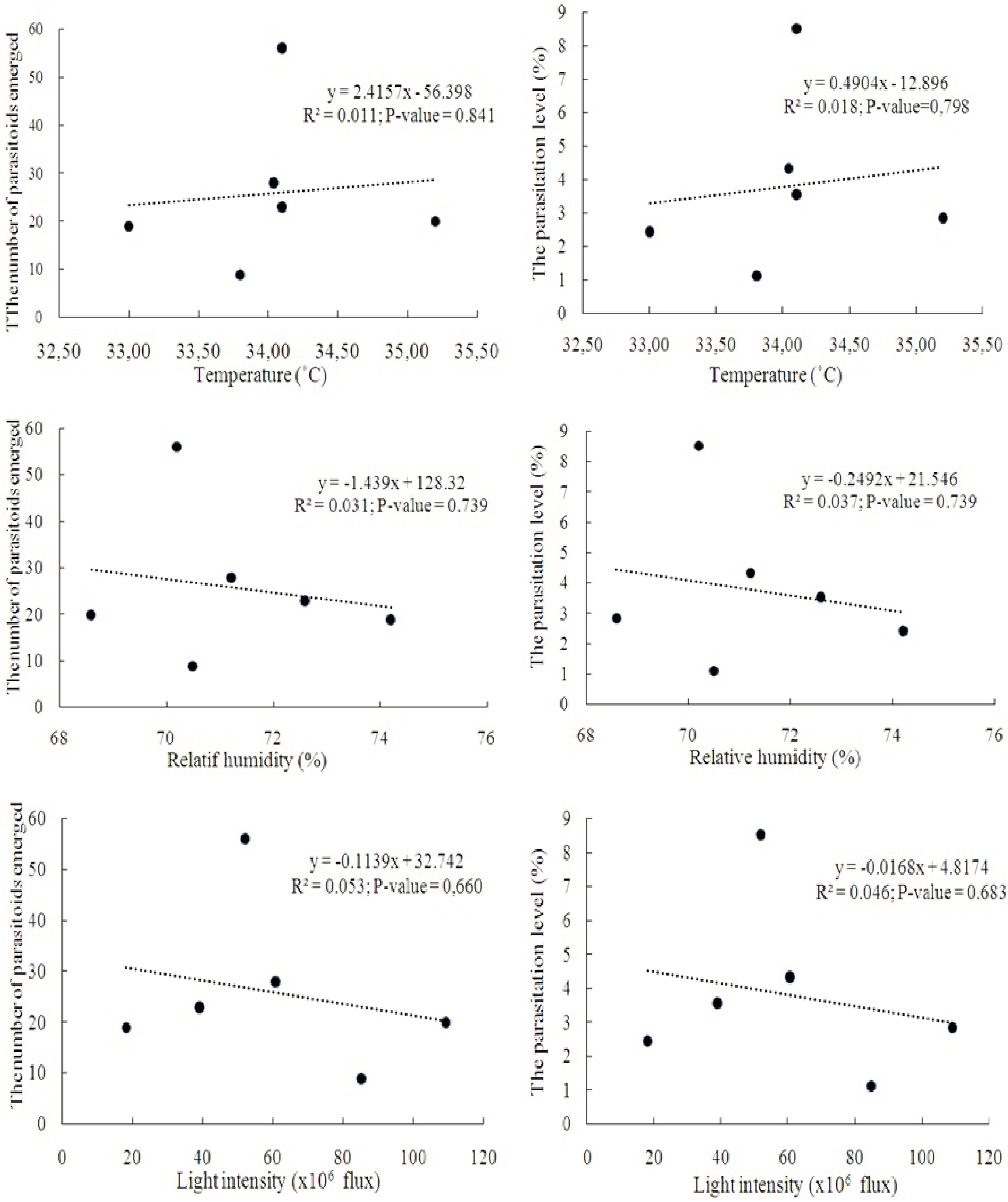

Figure 5. The relationship between micro climates in rice field used for trapping and the number of parasitoids emerged from *Nilaparvata lugens* eggs; trapping was conducted in 66 day old rice plantation (Inpari 23) in Kebonagung Village, Imogiri, Bantul

of egg parasitoids but did not affect their development (Chantarasa-Ard *et al*. 1984; Zhu *et al*. 1991).

The two genus (*Anagrus* and *Oligosita*) of the egg parasitoids were found from the trapping sites. Different location may have different diversity of egg parasitoids of *N. lugens*. Watanabe *et al*. (1992) reported that *Anagrus* spp. was the dominant species in Kampung Kandai, Alor Setar, Kedah, whereas in Kampung Gelam, Bk. Besar, Kedah the dominant species was *Oligosita* spp. Meilin (2012) found three species of egg parasitoids of *N. lugens* in Klaten and Yogyakarta: *Anagrus nilaparvatae*, *Oligosita* spp., and *Gonatocerus* spp. Furthermore, Abdilah (2015) found six species in four families of parasitoids of *N. lugens* eggs in Darmaga, Bogor, identified as *Anagrus nilaparvatae* (Mymaridae), *Anagrus* sp. (Mymaridae), *Gonatocerus* sp. (Mymaridae), *Tetrastichus formosanus* (Eulophidae), *Oligosita* sp. (Trichogrammatidae) and *Cyrtogaster* near *vulgaris* (Pteromalidae). These showed that the location of our research had lower diversity of egg parasitoids. Dewi (2005) reported that the stage of rice plants in fields affects the abundance of parasitoids. The older the rice plants, the smaller the number of parasitoids.

Our findings demonstrated that parasitoids of *N. lugens* eggs were active from morning to afternoon. Although the parasitism level decreased after 01.00 p.m., it suggest that the parasitoids remain in the rice ecosystem during the whole light period. This brings the consequense that application of insecticide at any time of the day would disrupt the function of parasitoids in regulating the population of *N. lugens.* However, application of insecticide in the early morning or late afternoon may have less effect on the parasitoids.

CONCLUSION

Two genera of parasitoids of *N. lugens* egg were recorded from Bantul, *Anagrus* and *Oligosita*. The parasitism occured as early as 05.00 a.m. and reached the highest from 11.00 a.m. to 01.00 p.m. The activity of parasitism was not affected by the microclimate of the rice ecosystem during the experiment. Considering the activity of parasitoid during the time of the day, application of insecticides should be done in the early morning or late afternoon to minimize the negative impacts to parasitoids.

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LITERATURE CITED

Abdilah, N.A. 2015. *Keanekaragaman dan Biologi Reproduksi Parasitoid Telur Wereng Cokelat,* Nilaparvata lugens *Stal. (Hemiptera: Delphacidae) [Diversity and Reproductive Biology of Eggs Parasitoid Brown Planthopper,* Nilaparvata lugens *Stal*. (*Hemiptera: Delphacidae)*]. Tesis. Institut Pertanian Bogor, Bogor. 75 p.

Anonymous. 2015. http://litbang.patikab.go.id/index.php/kajian-isu-strategis/195-faktor-faktor-penyebab-kematian-ibu-di-kabupaten-pati/202-analisis-kualitas-tanah-berdasarkan-kandungan-c-organik-n-total-p-tersedia-dan-k-tersedia-pada-sawah-sekitar-sungai-suwatu-margoyoso-pati, modified 20/12/15.

Budiman, A. 2014. *Waktu Oviposisi* Ostrinia furnacalis *dan Pengaruh Periode Terang terhadap Penetasan Telur (Time Oviposition of* Ostrinia furnacalis *and the Effect of Light on the Period of Hatching Eggs.*. Skripsi. Fakultas Pertanian. Universitas Gadjah Mada, Yogyakarta. 31 p.

Catindig, J.L.A, G.S. Arida, S.E. Baehaki, J.S. Bentur, L.Q. Cuong, M. Norowi, W. Rattanakam, W. Sriratanasak, J. Xia, & Z. Lu. 2009. Situation of Planthopper in Asia, p.191−220. *In* K.L. Heong & B. Hardy (eds.), *Planthopper: New Threats to the Sustainability of Intensive Rice Production Systems in Asia*. International Rice Research Institute, Los Banos, Philippines.

Chantarasa-Ard, S., Y. Hirashima, & T. Miura. 1984. Effects of Temperature and Food on the Development and Reproduction of *Anagrus incarnatus* Haliday (Hymenoptera: Mymaridae), an Egg Parasitoid of the Rice Planthoppers. *Esakia* 22: 145−158.

Dewi, L.P. 2005. *Potensi Parasitoid Telur Wereng Batang Padi Cokelat* Nilaparvata lugens *di Sleman Yogyakarta*. (*Potential Egg Parasitoid Brown Planthopper* Nilaparvata lugens *in Sleman, Yogyakarta).* Tesis. Universitas Gadjah Mada, Yogyakarta. 54 p.

Fleury, F. & M. Bouletreau. 1993. Effects of Temporary Host Deprivation on the Reproductive Potential of *Trichogramma brassicae*. *Entomologia Experimentalis et Applicata* 68: 203−210.

Garratt, M.P.D, D.J.Wright, & S.R. Leather. 2011. The Effect of Farming System and Fertilisers on Pests and Natural Enemies: A Synthesis of Current Research (Review). *Agriculture, Ecosystems and Environment* 141: 261−270.

Godfray, H.C.J. 1994. *Parasitoids Behavioral and Evolutionary Ecology*. Princeton University Press, Princeton, New Jersey, United Kingdom. 473 p.

Gurr, G.M., J. Liu, D.M.Y. Read, J.L.A. Catindig, J.A. Cheng, L.P. Lan, & K.L. Heong. 2011. Parasitoids of Asian Rice Planthopper (Hemiptera: Delphacidae) Pests and Prospects for Enhancing Biological Control by Ecological Engineering. *Annals of Applied Biology* 158: 149−176.

Macfadyen, S., R. Gibson, A. Polaszek, R.J. Morris, P.G. Craze, R. Planqué, W.O. Symondson, & J. Memmott. 2009. Do Differences in Food Web Structure between Organic and Conventional Farms Affect the Ecosystem Service of Pest Control? *Ecology Letters* 12: 229−238.

Meilin, A, Y.A. Trisyono, E. Martono, & D. Buchori. 2012. Teknik Perbanyakan Massal Parasitoid *Anagrus nilaparvatae* (Pang et Wang) (Hymenoptera: Mymaridae) dengan Kotak Plastik [Mass-Rearing Technique of *Anagrus nilaparvatae (*Pang et Wang) (Hymenoptera: Mymaridae) Using Plastic Box]. *Jurnal Entomologi Indonesia* 9: 7−13.

Meilin, A. 2012. *Dampak Insektisida pada Parasitoid Telur Wereng Batang Cokelat dan Deltametrin Konsentrasi Sublethal terhadap* Anagrus nilaparvatae *(Hymenoptera: Mymaridae) [The Effects of Deltamethrin Applied at Sublethal Concentrations on the Adults of* Anagrus nilaparvatae (Hymenoptera: Mymaridae)]. Disertasi Pascasarjana Universitas Gadjah Mada, Yogyakarta. 149 p.

Mutitu, E.K., J.R. Garnas, B.P. Hurley, M.J. Wingfield, M. Harney, S.J. Bush, & B. Slippers. 2013. Biology and Rearing of *Cleruchoides noackae* (Hymenoptera: Mymaridae), an Egg Parasitoid for the Biological Control of *Thaumastocoris peregrinus* (Hemiptera: Thaumastocoridae). *Journal of Economic Entomology* 106: 1979–1985.

Lou, Y.G., G.R. Zhang, W.Q. Zhang, Y. Hu, & J. Zhang. 2014. Reprint of: Biological Control of Rice Insect Pests in China. *Biological Control* 68: 103–116.

Page, T.L. 2003. Circadian Rhythms, p. 188–192. *In* V.H. Resh & T.C. Ring (eds.), *Encyclopedia of Insects*. Academic Press-Elsevier Science, Burlington, USA.

Reissig, W.H., E.A. Heinrichs, J.A. Litsinger, K. Moody, L. Fiedler, T.W. Mew, & A.T. Barrion. 1986. *Illustrated Guide to Integrated Pest Management in Rice in Tropical Asia*. International Rice Research Institute, Manila, Philippines. 411 p.

Thomson, L.J., S. Macfadyen, & A.H. Ary. 2010. Predicting the Effects of Climate Change on Natural Enemies of Agricultural Pests. *Biological Control* 52: 296–306.

Untung, K. 2006. *Pengantar Pengelolaan Hama Terpadu.* Edisi Kedua. (*Introduction of Integrated Pest Management.* 2nd edition.) Gadjah Mada University Press, Yogyakarta. 348 p.

Usmani, M.K. 2012. Biological Investigation on Some Species of Anagrus (Hymenoptera: Mymaridae), Egg Parasitoids of Leafhoppers (Hemiptera). *APCBEE Procedia* 4: 1–5.

Watanabe, T., T. Wada, & N.M.N.N. Salleh. 1992. Parasitic Activities of Egg Parasitoids on the Rice Planthoppers, *Nilaparvata lugens* (Stal) and *Sogatella furcifera* (Horvath) (Homoptera: Delphacidae), in the Muda Area, Peninsular Malaysia. *Applied Entomology and Zoology* 27: 205–211.

Zhu, Z.R., J.A. Cheng, & X. Chen. 1991. Effects of Temperature and Food on the Development, Survival and Reproduction of *Anagrus nilaparvatae* Pang et Wang (Hymenoptera: Mymaridae). *Acta Ecologica Sinica* 11: 66–72.