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Diversity of stored-product beetles at the rice warehouses in Mataram City and Central Lombok Regency, Indonesia

Keanekaragaman hama kumbang pada gudang beras di Kota Mataram dan Kabupaten Lombok Tengah, Indonesia

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ABSTRACT
Beetles, the order Coleoptera, are post-harvest rice product pests that cause severe quantitative and qualitative damage. Therefore, the diversity of pest beetles found in rice warehouses is essential because it leads to pest management by detecting and identifying beetles that can be the basis for making decisions in Integrated Pest Management (IPM). The study was conducted at two rice warehouses, Cakranegara I and Ubung, Indonesia, with rice sampling at five points diagonally on each side. Rice was taken using the Nobbe Trier tool inserted into the sack, and 100 g was taken as a rice sample. Rice sampling was conducted from June to July 2019, with five points diagonally on each side of a pile of rice. The results obtained four pest beetle species: *Sitophilus oryzae*, *Cryptolestes ferrugineus*, *Oryzaephilus surinamensis*, and *Tribolium castaneum*. Based on the Shannon Wiener index (H') in Cakranegara I warehouse, the pest beetle found was only *C. ferrugineus* with a low diversity level of 1.60. Meanwhile, four pest beetle species were found in the Ubung warehouse *S. oryzae*, *C. ferrugineus*, *O. surinamensis*, and *T. castaneum,* with a moderate diversity level of 2.74. The differences in the diversity of pest beetles in storage were influenced by the rice warehouse's temperature and relative humidity (RH).

ABSTRAK
Kumbang, ordo Coleoptera, merupakan hama pascapanen produk beras menyebabkan kerusakan serius baik secara kuantitatif maupun kualitatif. Keanekaragaman hama kumbang yang ditemukan di gudang beras sangat penting karena mengarah pada pengelolaan hama yang dilakukan dengan mendeteksi dan mengidentifikasi kumbang yang dapat menjadi dasar pengambilan keputusan dalam Pengelolaan Hama Terpadu (PHT). Penelitian dilakukan pada bulan Juni hingga Juli 2019 di dua lokasi gudang beras, Cakranegara I dan Ubung. Penelitian dilakukan pengambilan sampel beras pada lima titik secara diagonal pada setiap sisi tumpukan beras. Pengambilan beras menggunakan alat Nobbe Trier yang ditusukkan ke dalam karung, diambil 100 g beras sebagai sampel. Pengambilan sampel padi dilakukan lima kali dengan selang waktu tujuh hari. Dari hasil penelitian diperoleh empat spesies hama kumbang yaitu *Sitophilus oryzae*, *Cryptolestes ferrugineus*, *Oryzaephilus surinamensis,* dan *Tribolium castaneum*. Keanekaragaman hama kumbang berdasarkan nilai indeks Shannon Wiener (H') di gudang Cakranegara I ditemukan *C. ferrugineus* dengan tingkat keanekaragaman rendah yaitu 1.60. Sementara itu, di gudang Ubung ditemukan empat spesies hama kumbang *S. oryzae*, *C. ferrugineus*, *O. surinamensis*, dan *T. castaneum*, dengan tingkat keanekaragaman sedang sebesar 2.74. Perbedaan keanekaragaman hama kumbang dalam penyimpanan yang diamati dipengaruhi oleh suhu dan kelembaban relatif gudang beras.

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INTRODUCTION

Rice is the main food crop for more than 50% of the world's human population, and most of those who consume rice occur in developing countries (Liu et al., 2014). In Indonesia, rice is the main food commodity in complex economic problems and requires an approach to ensure food sufficiency. One of the measures to fulfill rice needs is storing rice during post-harvest. However, post-harvest losses (PHL) in rice as a grain product reach 10 to 20% due to storage pests (Phillips & Throne, 2010). In the current rice storage period, pest attacks can multiply economic losses due to the ability to infest rice quickly without being detected. Various biotic and abiotic environmental factors influence pests' establishment, colonization, and expansion in a specific geographic range. As an abiotic factor, the temperature is critical for several biological aspects of insects, such as survival, food consumption, growth and development, and fecundity (Ramadan et al., 2020). Pests that find optimal temperature and relative humidity conditions will reproduce explosively (Atungulu et al., 2019), especially beetles that can reproduce quickly and adapt to a supportive environment (Wagiman, 2014).

More than 600 species of coleopterans, 70 species of lepidopterans, and roughly 355 species of mites attack stored goods of agricultural and animal origin, resulting in both quantitative and qualitative losses (Rajendran & Sriranjini, 2008). The order Coleoptera is the most frequent post-harvest pest injurious to seeds (Berhe et al., 2022). Common varieties of pest beetles in rice are *Sitophilus oryzae* (Coleoptera: Curculionidae) (lesser grain weevil), *Cryptolestes ferrugineus* (Coleoptera: Laemophloeidae) (rusty grain beetle), *Oryzaephilus surinamensis* (Coleoptera: Silvanidae) (saw-toothed grain beetle), and *Tribolium castaneum* (Coleoptera: Tenebrionidae) (red flour beetle). Combining primary and secondary pests in one commodity can increase rice pest attacks. For example, *S. oryzae* can be a major pest in storage products with the ability to eat whole grains. Meanwhile, *O. surinamensis* and *T. castaneum* act as secondary pests by attacking grains previously infested by other pests and causing contamination of stored products. In addition to direct quantity and quality losses, insect attack is also associated with mycotoxin contamination through the distribution of fungal inocula and the creation of conditions that favor fungal growth and proliferation during storage (Milani, 2013).

Storage ecosystems are vulnerable to pest population explosions if not appropriately managed (Wagiman, 2014). Therefore, pest management in storage was carried out by detecting and identifying beetles that can be the basis for making decisions in IPM, which focuses on several factors: prevention, avoidance, suppression, and monitoring to prevent economic losses (Hagstrum & Athanassiou, 2019). Therefore, this study was conducted to determine the diversity of rice storage pest beetles at rice warehouses in Mataram City and Central Lombok Regency, Indonesia.

MATERIALS AND METHODS

Experimental site

The study was conducted at two Indonesian Bureau of Logistics (Bulog) storage locations with high rice storage capacity, Cakranegara I warehouse in Mataram City (8°36'35.1 "S 116°07'41.1"E) with a capacity of 12,000 tons and Ubung warehouse in Central Lombok Regency (8°38'55.9"S 116 °11'43.0"E) with a capacity of 10,000 tons as a storage place for the local rice, as shown in Figure 1. Rice sampling was carried out five times at seven days intervals. In addition, temperature and humidity data collection was collected using a digital thermometer placed in both rice warehouses.

Rice sampling

The study was conducted from June to July 2019 by diagonally taking rice samples at five points on each side of a pile of rice. Taking the rice using the Nobbe Trier tool inserted into the sack, 100 g was taken as the rice samples. Rice sampling modified the method by Setyaningrum et al. (2016) to make it easier to observe pest beetles. The rice samples were placed in a labeled Ziplock sterile plastic bag (39 cm × 25 cm). After that, the samples were sifted as previously described, and numbers of insects and different species were counted, then separated by pests in 70% alcohol to be identified at the Plant Protection Laboratory, Department of Agronomy, University of Mataram (UNRAM), West Nusa Tenggara, Indonesia.

Identification of pest beetles at the species level using a stereo microscope by comparing the morphological characteristics of insects from previous studies (Kumar, 2017; Schnitzler et al., 2014).

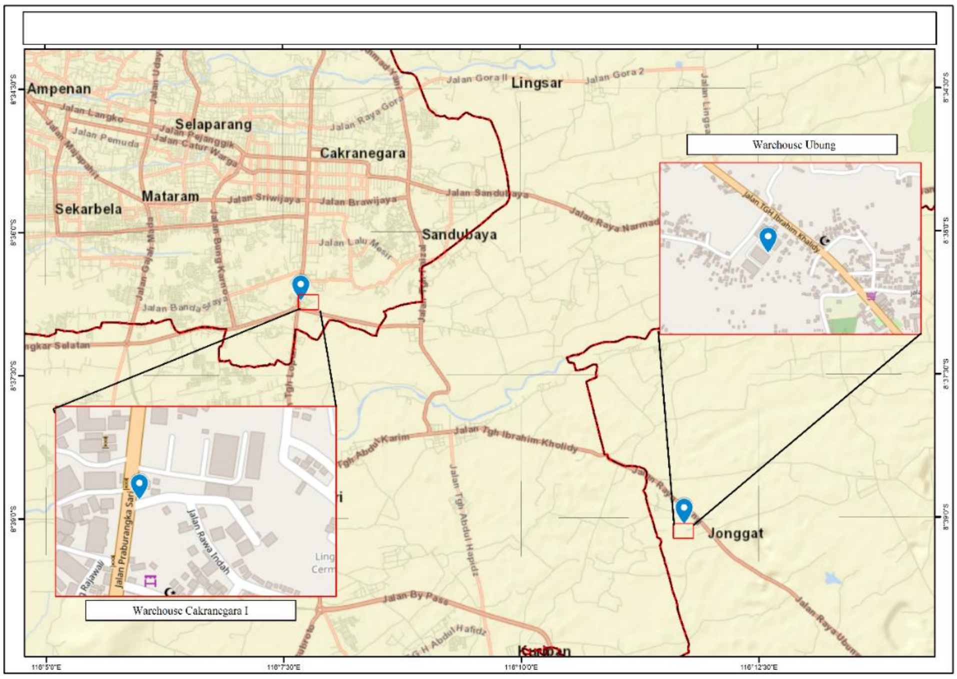

Figure 1. Cakranegara I in warehouse Mataram City (8°36'35.1"S 116°07'41.1"E) and Ubung warehouse in Central Lombok Regency (8°38'55.9"S 116 °11'43.0"E)

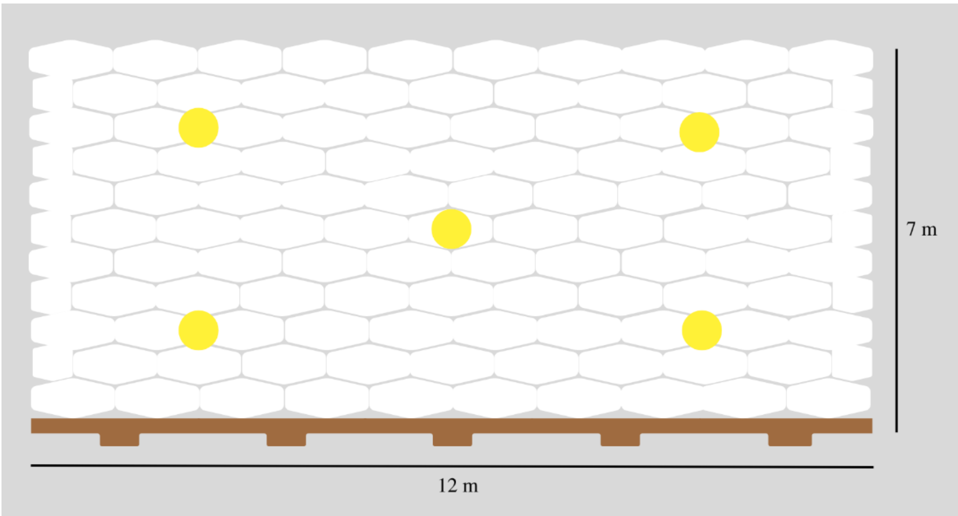

Figure 2. Sampling points on each side of the pile of rice

Statistical analysis of data

Pest beetle population

Statistical analyses were performed using Analysis of Variance (ANOVA) P<Fr 0.05. Before ANOVA, testing was carried out assuming a normal distribution and homogeneity. If there is a significant difference, then a post-hoc test with Tukey's Honestly Significant Difference (HSD) with P<Fr (* = 0.05, ** = 0.01, and *** = 0.001). The software was used for data analysis in SAS® OnDemand for Academics (ODA) via a web browser (https://welcome.oda.sas.com/login). The tables show mean ± standard error (SE).

Pest beetles diversity

The pest beetle diversity index was calculated using the equation of the Shannon Wiener Index (H') formula as follows:

$$H' = -\sum pi \ln pi$$

where:

H' = Shannon Wiener diversity index

Pi = number of individuals of a species/total number of all species

RESULTS AND DISCUSSION

Based on the result in Table 1, the insect population levels were different at the two locations. There were several possible reasons for these differences. The environment, such as temperature and relative humidity (RH), in the Cakranegara I warehouse was high than in the Ubung warehouse; the temperature of the storage warehouse in Cakranegara I was 31 ℃ and RH 63.4% and Ubung 28.6 ℃ and RH 64.6%, respectively. We know that temperature and RH in rice correlated with pest beetle. The relevance of environmental conditions was broadly recognized for the behavior and biology of insect pests of stored products (Athanassiou et al., 2019). The temperatures and RH were slightly higher in the Cakranegara I warehouse, increasing the development and survival rate and leading to higher insect populations. The temperature may also play a factor in the prevalence of different species. The high temperatures reported in the warehouses during many parts of the year may not have favored this species (Manu et al., 2018).

Four species of the pest beetle were found from the results of rice sampling, Cakranegara I warehouse was located *C. ferrugineus* and in the Ubung warehouse, four species of the pest beetle *S. oryzae* adults were the most frequent individuals collected in our study, followed by *C. ferrugineus, O. surinamensis,* and *T. castaneum*. According to Sumiati (2018) found pest beetles in Lombok in the study case Cakranegara II and Lembar warehouse that was *S. oryzae, T. castaneum, C. ferrugineus*, and *C. hemipterus*. Supportive environmental conditions influenced the number of pest populations. One environmental factor that supports the growth and development of insect populations in storage is temperature. The optimum temperature for the growth of the most common stored product insects ranges between 24–32 °C, while the lowest temperature below which the insect growth will be dramatically decreased is about 15 °C (Morrison et al., 2022). Storage pests growing well at an optimum temperature of 30 °C include *C. ferrugineus*, *O. surinamensis*, and *T. castaneum*. The temperature and humidity conditions in the Ubung warehouse had favorable temperatures and RH for the growth and development of these beetles.

Table 1. Mean ± SE of four pest beetle species in 100 g sample of rice from two different warehouses.

Species	Warehouse	
	Cakranegara I	Ubung***
Sitophilus oryzae	-	14.40 ± 1.96 a
Cryptolestes ferrugineus	69.80 ± 4.37	5.60 ± 1.20 ab
Oryzaephilus surinamensis	-	5.40 ± 1.32 ab
Tribolium castaneum	-	3.00 ± 0.70 b

Note: (-) = data not available; the number followed by the same warehouse locations in the same column has no significant difference based on Tukey's HSD test with P<Fr (* = 0.05, ** = 0.01, *** = 0.00, n = 5)

Sitophilus oryzae Linnaeus (Coleoptera: Curculionidae)

S. oryzae is a primary pests, particularly destructive, infesting numerous food grains, including rice, wheat, maize, sorghum, oats, rye, barley, and other cereals (Thangaraj et al., 2016). The high population of *S. oryzae* is influenced by feed factors, temperature, and RH. The temperature in the Ubung warehouse was suitable for the growth of *S. oryzae*. The development of *S. oryzae* at a temperature between 25–30 °C and RH 75% (Devi et al., 2017). In addition, the activity of *S. oryzae* increases the temperature and RH of the stored grains, which favors the growth and development of fungi and pathogens and causes grains to rot (Jian et al., 2012).

Cryptolestes ferrugineus Stephens (Coleoptera: Laemophloeidae)

C. ferrugineus is a cosmopolitan and one of the most destructive insect pests of stored products globally (Zhang et al., 2020). *C. ferrugineus* was affected by Cakranegara I and Ubung warehouses conditions where temperature and RH supported the development of its life. Therefore, it was observed that the condition of the warehouse when the research was carried out was suitable for its development. According to Rees (2004), rusty grain beetle lifecycle for 21 days at a temperature of 20 – 42 ℃ with RH 40–90%. Studies showed that adults *C. ferrugineus* prefer higher temperatures disperse more at high insect densities than at low densities. Adult *C. ferrugineus* move faster at higher temperature (35 °C) than at low temperature (20 °C) (Bharathi et al., 2022) and this temperature range was more expansive than their optimum temperature range (32 – 35 °C) for development (Howe, 1965).

Figure 3. Entire body lateral (scale bar = 1 mm) (a) *Sitophilus oryzae*, (b) *Cryptolestes ferrugineus*, (c) *Oryzaepilus surinamensis*, and (d) *Tribolium castaneum*

Oryzaephilus surinamensis Linnaeus (Coleoptera: Silvanidae)
O. surinamensis is a secondary severe grain pest (Shah et al., 2021; Vendl et al., 2019) spread globally through international trade (CABI, 2021). *O. surinamensis* can live in the range 20 – 38 °C. Under optimum conditions, the temperature of 30 – 32.5 °C and RH of 70 – 90%, the development of *O. surinamensis* from egg to imago is about 20 days (Rees, 2004). Therefore, the population of *O. surinamensis* influenced the temperature in the Ubung warehouse in accordance with their growth.

Tribolium castaneum Herbst (Coleoptera: Tenebrionidae)
T. castaneum is the secondary pest as one of the main factors in infestation and damaging food products other than primary pests such as *S. oryzae* (Mutters & Thompson, 2009). This pest is more damaging to processed cereals in the form of flour than whole-grain cereals (Zakka et al., 2013). The population will increase when other types of insects attack the material. Brijwani et al. (2012) reported that at the relatively low temperature (25 °C and 75% RH), the red flour beetle takes several days or months to lay its eggs (about 150 – 600 eggs, on average 2 –11 eggs/day), while at high temperatures (35 °C and 75% RH) it lays eggs within 2 – 3 days. This species was underdeveloped due to environmental factors in the Ubung warehouse.

Diversity of pest beetle
Table 1 shows the population per observation variables of the appearance of pest beetles in Cakranegara I and Ubung warehouses. In the Cakranegara I warehouse, it was found only *C. ferrugineus* species with a population of 69.80. Meanwhile, the Ubung warehouse found four pest beetles species *S. oryzae* with a population of 14.40, *C. ferrugineus*

with a population of 5.60, and *O. surinamensis* with a population of 5.40, and *T. castaneum* with a population of 3.00. Therefore, *C. ferrugineus*, *O. surinamensis*, and *T. castaneum* did not show high individuals because both were secondary pests (Zulaikha et al., 2018). Accordingly, the secondary pest was likely labeled as one of the main factors in infestation and damaging food products other than primary pests such as *S. oryzae* (Mutters & Thompson, 2009). However, there was no correlation between temperature and insect numbers in maize (Danso et al., 2018).

The diversity of pest beetle was the number of pest species found in rice storage in Cakranegara I and Ubung warehouse. The variety of pest beetle species will affect the damage to rice in storage. In this study, the data taken from the number of families and the total individual pest beetle obtained by the sampling method determined the diversity of pest beetle species. The diversity index of beetles at the two rice warehouses can be seen in Table 2.

Table 2. Diversity index of pest beetle in each rice warehouse

Observation Variables	Warehouses	
	Cakranegara I	Ubung
Total Individual (N)	349	142
Total Species	1	4
Shannon-Wiener Diversity Index (H')	1.6	2.74

Note: The pest beetle diversity index was calculated using the Shannon-Wiener formula

The diversity index (H') describes the stability of the community. The high diversity of pest beetle affects the damage to rice commodities. A community with a score of $1<H'<2$ indicates low species diversity if $2<H'<3$ indicates moderate diversity, and if a value of $3<H'<4$ indicates high diversity. Table 2 shows that the Ubung warehouse found four species of *S. oryzae* pests, *C. ferrugineus*, *O. surinamensis*, and *T. castaneum,* with moderate diversity levels of 2.74. In the Cakranegara I warehouse, *C. ferrugineus* had a low diversity level of 1.60. The diversity of pest beetle species in warehouse Ubung was higher than in Cakranegara I, which indicated potential damage to commodities in the storage.

Sanitation can be essential in reducing pest populations and preventing outbreaks. Increased sanitation would reduce beetles within the warehouse and lower pest populations (Abdelghany et al., 2010). Initial pest populations may have been the same in the two locations, but the poorer sanitation conditions in Cakranegara I might have allowed for the much higher populations *C. ferrugineus*. Finally, the temperatures and RH were slightly higher, increasing the development and survival rate and insect populations. In contrast, *S. oryzae* and *T. castaneum* were exposed to high-temperature shock, survival rates decreased (Abdel-Hady et al., 2021). Other possible reasons for the differences in the pest population were the number and effectiveness of fumigations, the use of contact insecticides, and the duration of storage. Both warehouses fumigated their stock with phosphine, but we did not examine the efficacy of fumigations. Further studies would be required to determine which factors were responsible for the higher insect population in Cakranegara I.

CONCLUSIONS

Four major pest beetle species were harmful in two warehouses; there were *S. oryzae*, *C. ferrugineus*, *O. surinamensis*, and *T. castaneum*. The temperature and RH of warehouses supported a species of pest beetle. The attack of these species in rice warehouses damages the rice's quality. Therefore, it was crucial to know about developing a control method that adversely affects humans and the environment.

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