A preliminary study of orthopterans biodiversity in the paddy fields of Sleman Regency, Special Region of Yogyakarta

B E Yudharta¹, A Setyaningrum¹, O A Safa’ah¹, N K Widiasri¹, F Triaswanto² and S Sukirno²

¹Undergraduate Program, Faculty of Biology, Universitas Gadjah Mada
Jl. Teknika Selatan, Sekip Utara, Bulaksumur, Yogyakarta 55281, Indonesia
²Entomology Laboratory, Faculty of Biology, Universitas Gadjah Mada
Jl. Teknika Selatan, Sekip Utara, Bulaksumur, Yogyakarta 55281, Indonesia

E-mail: besta.e.y@mail.ugm.ac.id

Abstract. This study was conducted to study orthopterans biodiversity in the paddy fields of Sleman Regency. This research was conducted on the paddy fields of Sleman which were divided into two lines (Palagan and Cangkringan lines). The variations of altitude are 150-250 masl, 260-350 masl, 360-450 masl, and 460-550 masl. Observations were performed by purposive sampling. The environmental parameters, such as humidity, light intensity, and temperature, were measured. Diversity of orthopteran was analyzed using Shannon - Wiener index (H’) and Evenness index (E’). We found 4.417 individuals which consisted of nineteen species, sixteen genera, and five families. The most dominant species were Oxya japonica, Gesomula mundata, and P. fumosa, while Caryanda spuria, Euconocephalus pallidus, and Paratettix sp. were minor species. The highest diversity and evenness of orthopteran in Palagan line was at P4 (H’ = 1.836, E’ = 0.678), and in Cangkringan line was at C4 (H’ = 2.098, E’ = 0.755). The lowest diversity and evenness of orthopteran in Palagan line was at P2 (H’ = 1.141, E’ = 0.433), and in Cangkringan line was at C2 (H’ = 0.989, E’ = 0.375). Correlation value between altitudes with individuals, diversity, and evenness were -0.069, -0.676, and -0.530, consecutively.

1. Introduction

Paddy is a staple food for almost all Indonesian people because it contains high carbohydrates. Paddy is one of the main commodities in the agricultural industry in Indonesia. Every year, demand for paddy continues to increase in parallel with the human population. Therefore paddy production becomes one of the serious problems that must be solved. Paddy production can be affected by climatic factors like unpredictable weather. Besides, paddy production may also decrease due to attacks of various pests [1]. Some pests come from the Order of the Orthoptera. The order of the Orthoptera, which became agricultural pests and forests, generally originated from the Acridoidea family. Acridoidea is one of the Supra Familia of the Caeliferina suborder or grasshoppers with short antennae [2]. Grasshopper has a very important role in the ecosystem such as stimulating crop growth, becoming a prey in a food web, creating crop litter for the soil, and as a cycle of elements in an

¹Corresponding author
ecosystem [3]. Paddy field agroecosystem is a suitable habitat for most of the orthopteran. This is due to the availability of food and habitat which support the development of Orthoptera.

Some species from the order of Orthoptera are phytophagous. This made orthopterans may ruin the crop and become pests [4]. Lampung Province is one of the provinces that have been attacked by Locust. In May 1998, locust had attacked 6,818 ha on paddy and cornfields that spread in 43 sub-district of 83 sub-district in Lampung province (51.8%) [5]. Some families of the orthopteran are classified as pests in paddy fields such as Acrididae, Tettigoniidae, Gryllotalpidae, and Pyrgomorphidae [6]. Furthermore, the most discovered family in the paddy fields are Acrididae and Pyrgomorphidae [7]. Another study indicates that the most popular families found in paddy fields are Acrididae and Pyrgomorphidae [8]. Meanwhile, the family Acrididae may act as pests because they include phytophagous insects while Tettigoniidae and Gryllidae are predatory insects [4].

According to the BPS-Statistics Indonesia, Sleman Regency has an altitude that may be divided into several classes such as, less than 100 masl, 100-499 masl, 500-999 masl, and more than 1000 masl [9]. Altitude can affect the existing environmental parameters, so it can affect the diversity that appears at every altitude. The aim of this research was to study orthopterans biodiversity in some areas of paddy fields in Sleman Regency, Special Region of Yogyakarta. This study was important to provide a database of orthopteran that was useful for insect pest management of paddy fields.

2. Methods

2.1. Study area

This study was conducted from December 2019 to January 2020. We carried out the research in Sleman, especially in two lines, the Palagan line and Cangkringan line. Four paddy fields with an altitude of about 150-250 masl, 260-350 masl, 360-450 masl, and 460-550 masl were chosen in every line as sampling sites of this study (Figure 1).

Table 1. The sampling sites description of the study of orthopteran diversity in Sleman, Yogyakarta

| Paddy Field | Altitude (masl) | Absolute Location | Paddy Varieties | Age of Paddy (day) | Irrigation Type | Vegetation |
|-------------|----------------|------------------|-----------------|-------------------|----------------|------------|
| Palagan line |                |                  |                 |                   |                |            |
| P1          | 479            | -7.640278, 110.455556 | Sahera         | 120               | by river       | Cassava, dasheen, and grasses. |
| P2          | 420            | -7.660278, 110.392222 | Padi ketan     | 45                | by river       | Paddy, grasses, chilli, silk tree, and banana. |
| P3          | 320            | -7.885556, 110.382778 | Inpari 30      | 14                | the wells      | Sugarcane plants and grasses. |
| P4          | 240            | -7.701389, 110.333889 | IR 64          | 50                | by river       | Lemongrass, elephant grass, cassava plant, and banana trees. |
| Cangkringan line |          |                  |                 |                   |                |            |
| C1          | 460            | -7.651667, 110.443889 | Melon          | 80                | by river       | Grasses, coconut trees, and banana trees. |
Based on Table 1 above, there are six different varieties of paddy; IR64, Inpari 30, Sahera, Melon, Ketan, and Legowo. Most of the paddy fields use irrigation by the river as an irrigation system, except for field P3 which uses water from the wells. In most fields, the major vegetation that may be found was grasses.

|     |     |    |       |       |     |     |
|-----|-----|----|-------|-------|-----|-----|
| C2  | 423 | -7.115278, 110.718333 | Legowo | 30 | by river | Bushes, grasses, and coconut trees.
| C3  | 300 | -7.689444, 110.449444 | Sahera | 50 | by river | Bushes and grasses.
| C4  | 213 | -7.189722, 110.698612 | IR 64  | 80 | by river | Bushes, grasses, and trees with canopy.

Based on Table 1 above, there are six different varieties of paddy; IR64, Inpari 30, Sahera, Melon, Ketan, and Legowo. Most of the paddy fields use irrigation by the river as an irrigation system, except for field P3 which uses water from the wells. In most fields, the major vegetation that may be found was grasses.

**Figure 1.** The sampling sites of study of orthopteran diversity in Sleman paddy fields, Yogyakarta.

2.2. *Collection and identification of insects*

Purposive sampling was conducted to collect the insects, especially orthopterans. In each sampling location, three sampling points were used as repetition. One person was located at each point and collected the insects. Sampling was conducted six times in two days which interval eight days. Afterward, insect samples were identified in the laboratory based on their whole body morphological features using iNaturalist as the reference. (https://www.inaturalist.org/)

Preservation was initiated by killing the specimens using a killing bottle. Afterward, identified samples mounted using insect pins. When all of the pinning processes were done, samples were dried with a drying box (34 cm x 23 cm x 22 cm) using a five watt Panasonic LED bulb in one day and tagged with a label on it.

2.3. *Environmental parameters measurement*

The parameters measured in this study were temperature, air humidity, and light intensity. Temperatures were measured with a thermometer, humidity with an analog hygrometer, and light intensity using the lux meter (Smart Sensor Digital Lux Meter AS803).

2.4. *Data analysis*

After sampling, insect biodiversity was determined using species diversity and species evenness. In each sampling site, a total of individuals were counted and tabulated. After that, species diversity and...
species evenness were calculated. Species diversity index was measured using Shannon-Wiener Index (H'). Species evenness index was measured using Evenness Index (E').

2.4.1. Index of diversity. We measured the index of diversity using the following equation [10].

\[
H' = - \sum_{i=1}^{k} p_i \ln p_i
\]

(1)

Which:

H' : index of diversity
pi : each species proportion

Diversity levels are divided into three types. If H' less than 1.5, diversity level in one location is classified as low one, if H' between 1.5 to 3.5, the community classified as moderate level, and H' more than 3.5, the community is classified as the high level [10].

2.4.2. Index of evenness. The index of evenness was measured using the following equation [10].

\[
E' = \frac{H'}{\ln S}
\]

(2)

Which:

E' : Evenness Index
S : Total of species found

The range value of evenness index is 0 (uneven) up to 1 (even) [11]. If E' less than 0.5, the population might be in pressured condition. When the value of E’ is between 0.5 to 0.75, the population is not in stable condition. And if the value of E’ is between 0.75 to 1.0, the population is in stable condition [12].

2.4.3. Correlation. To study the correlation between altitude with total individuals, total species, evenness index, and diversity index were analyzed with SPSS 20.

3. Results
We collected a total of 4,417 individuals consisting of nineteen species from sixteen genera that belonged to five families (see Figure 2).
Figure 2. Orthopterans species found in Sleman paddy fields, Yogyakarta (Scale bar: 10 mm).

We found 10 species from Acrididae, 4 species from Tettigoniidae, 2 species from Gryllidae, and 1 species from Pyrgomorphidae. Species belonging to the Acrididae family namely Achurum carinatum, Acrida sp., Caryanda spuria, Gastrimargus marmoratus, Gesonula mundata, Oxya japonica, Phlaeoba fumosa, Phlaeoba infumata, Trilophidia annulata, and Valanga nigricornis. Achurum carinatum has elongated, reduced wing and no spine between forelegs [14]. Acrida sp. has a long head shape with a yellowish green body and can make a sound when flying [15]. Caryanda spuria has a yellowish body with black pattern and has hind legs with a blue and turquoise pattern [16]. Gastrimargus marmoratus has a brownish body, hind femur with black spot, hind tibia red with yellow band, and has a pronotum that is twice as long as the head [17]. Gesonula mundata has a greenish-brown body with a light green band starting from each eye which continues to the tegmen episternum and a smooth and shiny integument [18]. Oxya japonica has a dark brownish green body color with black band starting from each eye along the superior margin of the lateral lobe which continues to the tegmen [18]. Phlaeoba fumosa has a brown body with yellowish band, tympanum located in the first abdomen, and has reddish tibia [19]. Phlaeoba infumata has a small to medium body size, dark brown body color, short ensiform antennae, and straight lateral carinae pronotum [15]. Trilophidia annulata has a dark brown variety with yellowish body color, filiform antennae, and has a hind femur with light colored circular lines [20]. Valanga nigricornis has a yellowish body varied with brown color, femur with a pair of black markings, and spines under the prosternum [18]

Species belonging to the Tettigoniidae family are Conocephalus cognatus, C. maculatus, C. fasciatus, and Euconocephalus pallidus. Conocephalus cognatus has saddle-shaped pronotum [21]. Conocephalus maculatus has a small and slender body (20-26 mm), the wings exceed the abdomen [21]. Conocephalus fasciatus has hindwings and tegmina that exceeds the abdomen and the stout teeth
are present in male cerci [22]. *Euconocephalus pallidus* has short fastigium, elongated pronotum, brown antennae, wings and tegmen are fully developed [23]. Species belonging to the Tetrigidae family are *Scelimena producta* and *Paratettix* sp. *Scelimena producta* has pronotum length of less than 21 mm in female and less than 19 mm in male, the fastigium is short (around the width of the eye) [24]. *Paratettix* sp. has body length less than 20 mm, pronotum extends above the abdomen (not exceeds the abdomen), frons and dorsum pronotum are less wavy [25][26]. Species belonging to the Gryllidae family are *Euscyrtus concinnus* and *Nisitrus* sp.. *Euscyrtus concinnus* has antennae (more than the total body length) [18]. *Nisitrus* sp. has a slender body, wasp-like and colorful body, the eyes are yellow green and have a black stripe on the dorso-ventral side, narrow fastigium [27]. Species belonging to the Pyrgomorphidae family is *Atractomorpha* sp. that has green-colored elongated body, cone-shape head, fastigium around the length of the eye, oblong eyes [28].

**Table 2.** Orthopterans distribution and abundance in Sleman paddy fields (P4: Palagan 4 240 masl; P3: Palagan 3 320 masl; P2: Palagan 2 420 masl; P1: Palagan 1 479 masl; C4: Cangkringan 4 213 masl; C3: Cangkringan 3 300 masl; C2: Cangkringam 2 423 masl; C1: Cangkringan 1 460 masl)

| No | Samples            | P4 | P3 | P2 | P1 | C4 | C3 | C2 | C1 |
|----|--------------------|----|----|----|----|----|----|----|----|----|
| 1  | *Achurum carinatum* | +  | +  | +  | -  | +  | -  | +  | -  | -  |
| 2  | *Acrida* sp.       | +  | +  | +  | +  | +  | +  | +  | -  | -  |
| 3  | *Atractomorpha* sp.| +++| +  | +  | +  | +  | +  | +  | +  | +  |
| 4  | *Caryanda spuria*  | -  | -  | -  | -  | +  | -  | -  | -  | -  |
| 5  | *Conocephalus cognatus* | +  | +  | +  | -  | +  | +  | +  | +++| |
| 6  | *C. fasciatus*     | -  | -  | +  | -  | -  | -  | -  | -  | -  |
| 7  | *C. maculatus*     | +  | +  | +  | +  | +  | +  | +  | -  | -  |
| 8  | *Euconocephalus pallidus* | -  | -  | -  | -  | -  | -  | -  | -  | -  |
| 9  | *Euscyrtus concinnus* | +  | +  | +  | +  | +  | +  | +  | +  | +  |
| 10 | *Gastrimargus marmoratus* | +  | +  | -  | +  | ++ | -  | -  | -  | -  |
| 11 | *Gesonula mundata*  | +  | +  | +  | +  | -  | +  | +++| |
| 12 | *Nisitrus* sp.     | +  | +  | +  | -  | +  | +  | +  | +  | +  |
| 13 | *Oxya japonica*    | +++| +++| +++| +++| ++ | +++| +++| +++| +++|
| 14 | *Paratettix* sp.   | -  | +  | -  | -  | -  | -  | -  | -  | +  |
| 15 | *Phlaeoba fumosa*  | +++| +  | +  | +  | +++| +  | -  | -  | -  |
| 16 | *P. infumata*      | +  | +  | +  | +++| -  | +  | +  | +  | +  |
| 17 | *Scelimena producta* | -  | +  | -  | -  | -  | -  | -  | +  |
| 18 | *Trilophidia annulata* | +  | +  | +  | +  | +  | +  | +  | +  | -  |
| 19 | *Valanga nigricornis* | +  | +  | -  | -  | +  | +  | -  | +  | -  |

Notes:
- : the number of individual, zero
+ : the number of individual, one up to fifty
++ : the number of individual, fifty one up to one hundred
+++ : the number of individual, more than one hundred
Table 2. showed the distribution and abundance of orthopterans in Sleman paddy fields based on different altitude levels. *Atractomorpha* sp., *Euscyrtus concinnus*, and *Oxya japonica* were found in both the Palagan and Cangkringan line. The most abundant species in Palagan were *Oxya japonica*, *Atractomorpha* sp., and *Phlaeoba fumosa*. The most abundant species in Cangkringan were *Conocephalus cognatus*, *Geosoma mundata*, *Oxya japonica*, *Phlaeoba fumosa*, and *Phlaeoba infumata*. Meanwhile, *Euconocephalus pallidus* and *Conocephalus fasciatus* were only found at P4.

Table 3. The correlation between total individuals, diversity index, and evenness index with altitudes in Sleman paddy fields.

| Location | Temperature (°C) | Humidity (%) | Light intensity (lux) |
|----------|-----------------|--------------|----------------------|
| P4       | 29 – 34         | 32 – 51      | 92,820 – 109,800     |
| P3       | 28 – 31         | 36 – 50      | 85,810 – 108,700     |
| P2       | 25 – 31         | 19 – 52      | 94,410 – 124,800     |
| P1       | 25 – 32         | 15 – 46.5    | 94,880 – 108,700     |
| C4       | 29 – 33         | 39 – 46      | 87,090 – 128,000     |
| C3       | 28 – 33         | 28 – 43      | 42,460 – 133,800     |
| C2       | 28 – 33         | 28.5 – 50    | 31,530 – 116,500     |
| C1       | 27 – 31         | 43 – 46      | 95,210 – 219,200     |

Based on Table 4. it can be seen that the range of temperature, humidity, and light intensity in Palagan (P4 – P1) were 25 – 34°C, 15 – 46.5%, and 85,810 – 124,800 lux. Meanwhile, in Cangkringan (C4 – C1) the ranges of temperature, humidity, and light intensity were 27 – 33°C, 28 – 50%, and 31,530 – 219,200 lux.

4. Discussion

According to research in the Sleman paddy fields area, three out of nineteen species can be found at all sampling sites. They are *Atractomorpha* sp., *Oxya japonica*, and *Euscyrtus concinnus*. They are easy to find because their food preferences are abundant in the paddy field [29]. During the sample collection, they were observed eating the paddy leaves. Thus, they potentially become a major pest. *Oxya japonica* was the largest number of species in most locations except in C4. At this site, the most numerous species is *Phlaeoba infumata*. Due to the use of insecticides in C4, the grasshoppers migrate to the surrounding grassland. The high grasslands are most suitable for *P. infumata* so that *Oxya*
japonica loses in the competition [30]. We found several species with limited distribution such as Caryanda spuria, Conocephalus fasciatus, Euconocephalus pallidus, and Paratettix sp. The number of Caryanda spuria specimens was very low because their body color is striking contrasts with the environment and their wings are not fully developed, which may cause easily detected by their predators. Conocephalus fasciatus and Euconocephalus pallidus were found at P2 only. That sampling site had a different irrigation system named “mina padi”, thus allowing the habitat to contain more water. The family members of Tettigoniidae such as Conocephalus fasciatus and Euconocephalus pallidus prefer to eat wet food resources and live in a humid habitat [31]. The humidity of the paddy field in P2 can reach up to 52%, which is higher than the other sampling sites. Paratettix sp. was found at P3 and C2. That is because these places had high air humidity between 36 – 50%. Insects from Tettigidae’s family were highly adapted in a humid environment [32].

The diversity index is commonly used for knowing the species diversity [33]. Based on the diversity index obtained, it showed that the diversities of P4, P3, P2, and P1 were moderate, low, low, and moderate, respectively. While the diversities at the Cangkringan line were moderate for C4 and C3 and low for C2 and C1. Although the conditions of diversity are various, however, both in the Palagan and Cangkringan show the same pattern where the index of diversity tends to decrease with the rise in altitude, except in the highest altitude (P1 and C1). In the highest altitude, the paddy field is surrounded by groves, thus allowing some species to migrate from the groves to the paddy field. The P4 and C4 have the highest H’ value. Both locations had a relatively high temperature of 29 – 34°C causing the highest diversity of Orthoptera. Meanwhile, the lowest H’ value was measured at P2 and C2. Both places had a relatively high humidity of 28 - 52% causing the lowest Orthoptera diversity. This is because Orthoptera is generally adaptable in the hot and dry habitat and vice versa [34]. The H’ value was lowest in C2 compared with other locations. On the other hand, C3 had the smallest number of specimens, however, the diversity index was higher than C2. The H’ value is determined by the number and evenness of species. The value of H’ will increase along with the increase in the number and evenness of species [12]. The paddy field in C2 had abundant species but was only dominated by Oxya japonica. Other species were only found in a small number, so the species distribution was uneven. Meanwhile, in C3, although only a few specimens were found, there were no dominant species. So the species distribution was even. Based on interviews obtained with the field owner, the paddy field in C3 was sprayed with insecticides. In addition, the paddy field is not surrounded by grassland so the insect food preference is insufficient, consequently, the insects migrate to the other location. The evenness index (E’) is generally used to measure the degree of species evenness in a particular community [35]. The E’ values measure for P1 and P4 indicate that the population was in an unstable condition. Meanwhile, the E’ values for P2 and P3 show that the population was in a depressed condition. The paddy field in P4 was dominated by Atractomorpha sp., Oxya japonica, and Phlaeoba fumosa. While in P1, P2, and P3 were dominated by Oxya japonica. The dominance of a certain species indicates that other species have lost the competition. The orthopteran population in C4, C3, C2, and C1 were stable, unstable, depressed, and unstable, respectively. The paddy field in C4 was dominated by Phlaeoba fumosa and Phlaeoba infumata, even though Oxya japonica and Acrida sp. were still abundant. At that location, there is a large grassland which may reduce the intensity of interspecies and intraspecies competition. During data collection, each species inhabited a different spot. Phlaeoba fumosa and Phlaeoba infumata were abundant in high grassland, meanwhile, Acrida was abundant in low grassland. Oxya japonica was easily found on the edge of the paddy field or the grass closest to the field. In the C2, depressed population conditions were caused by the dominance of Oxya japonica. Paddy field condition in C1 was dominated by three species, namely Conocephalus cognatus, Gesonula mundata, and Oxya japonica. Meanwhile, in C3, the most commonly found species were Gastrimargus marmoratus and Oxya japonica, but the numbers of specimens were the smallest compared with other locations.

According to correlation analysis obtained, the paddy field altitudes were negatively correlated with the total of individuals, diversity index, and evenness index. As the altitude was raised, the total individuals, diversity index, and evenness index tend to be decreased. The range of temperature and
humidity became wider when in higher altitudes. The most extreme humidity range was in P2 and P1 that had humidity ranges of 33% and 31.5%, respectively. The orthopterans prefer the dry habitat [34], which may cause they were not abundant in humid habitats. Even though, orthopterans biodiversity in P1 were moderate (based on diversity index) because the paddy field was surrounded by a large grassland that may cause the orthopterans migrate from the grassland to paddy field and vice versa. The smallest range for humidity was found at C1 but the index diversity was low. The humidity range was not extreme, but the orthopterans food preferences were limited in the paddy field only because there were no groves or grassland found near the paddy field.

This research can be used as a database for the insect pest management of paddy fields in the Sleman area. Besides, this study provides data on the diversity of insects from order Orthoptera in several paddy fields of Sleman. This research can still be developed and optimized, one of which is by providing variables of the influence of seasonal differences, so that the level of diversity and evenness of the orthopterans in the Sleman region during the rainy and dry seasons can be known.

5. Conclusion
Based on the discussion above, it can be concluded that orthopterans which had the highest value of diversity and evenness were found in the altitude range of 150 – 250 masl, while the lowest value of diversity and evenness were in the altitude range of 360 – 450 masl. The higher the location of the paddy field in the Sleman, the diversity and evenness value tends to decrease. In addition, the correlation between paddy field altitudes with the total of individuals, diversity index, and evenness index were negative.

6. Acknowledgment
The author would like to thank I Gusti Made Raka Alpin Aditya who has helped in the sampling process, then to the Laboratory of Entomology, Faculty of Biology, Universitas Gadjah Mada, that provide sampling equipments and materials, and also thanks to all the owners of the paddy fields who have allowed their paddy field to be used as a research location.

7. References
[1] Dewati R and Waluyati L R 2018 Agro Ekon. 29 161-172
[2] Nayeem R and Usmani K 2012 Munis Entomol. Zool. 7.1 391-417
[3] Van Hook R I 1971 Ecol. Monogr. 41 1-26
[4] Jauharlina J, Hasnah H, and Taufik M I 2019 J. Agric. Sci. 41(2) 316 - 324
[5] Sudarsono et al. 2011 J. Trop. HPT 11(1) 95-101 in Indonesia.
[6] Ane N U I and Hussain M 2016 J. Entomol. Zool. Stud. 4(1) 36-41
[7] Akhtar Md H et al. 2012 Ann. Biol. Res. 3(5) 2190-93
[8] Usmani M K, Nayeem M R and Akhtar M H 2012 Eur. J. Exp. Biol. 2(5) 1912-17
[9] BPS-Statistics Indonesia Sleman District 2019. Luas panen, produksi dan rata-rata produksi jagung dirinci per Kecamatan di Kabupaten Sleman, 2017 dan geografi Kabupaten Sleman. From: https://slemankab.bps.go.id/subject/53/tanaman-pangan.html Accessed on November 18th 2020 in Indonesia.
[10] Friamsa N, Wijtjaksono, and Wijanarko A 2018 Indones. J. Plant Prot. 22(1) 20-26
[11] Payne L et al. 2005 Ecol. Appl. 15(2) 507-520
[12] Krebs C J 2014 Ecology The Experimental Analysis of Distribution and Abundance Sixth Edition. (Harlow: Pearson Education Limited)
[13] Tan M K 2011 Nat. Singapore 4 31-42
[14] Achurum carinatum (F.Walker, 1870) in GBIF Secretariat (2019). GBIF Backbone Taxonomy. Checklist dataset https://doi.org/10.15468/39omei accessed via GBIF.org on 2020-11-24.
[15] Gupta S K and Chandra K 2017 J. Asia-Pacific Biodivers. 10 91-103
[16] Caryanda spuria (Stål, 1861) in GBIF Secretariat (2019). GBIF Backbone Taxonomy. Checklist dataset https://doi.org/10.15468/39omei accessed via GBIF.org on 2020-11-24.
[17] *Gastrimargus marmoratus* (Thunberg, 1815) in GBIF Secretariat (2019). GBIF Backbone Taxonomy. Checklist dataset https://doi.org/10.15468/39omei accessed via GBIF.org on 2020-11-24.

[18] Sugiar A 2018 *Invent. of Insect in Serdang Menang Village* 1-4

[19] *Phlaeoba fumosa* (Serville, 1838) in GBIF Secretariat (2019). GBIF Backbone Taxonomy. Checklist dataset https://doi.org/10.15468/39omei accessed via GBIF.org on 2020-11-24.

[20] *Trilophidia annulata* (Thunberg, 1815) in GBIF Secretariat (2019). GBIF Backbone Taxonomy. Checklist dataset https://doi.org/10.15468/39omei accessed via GBIF.org on 2020-11-24.

[21] Tan M K 2012 *Nat. Singapore* 5 343-350

[22] Bland R G 2003 *The Orthoptera of Michigan* (Michigan: Michigan State University Extension) p 45

[23] Panhwar W A et al. 2014 *Int. J. Adv. Res.* 2 268-277

[24] Muhammad A Q et al. 2018 *An Annotated Catalogue of the Pigmy Grasshopper of the Tribe Scelimenini Bolivar, 1887 (Orthoptera: Tettigidae with Two New Scelimena Species From the Malay Peninsula and Sumatra* (Auckland: Magnolia Press) pp 42-49

[25] Lehmann A W et al. 2017 *ZooKeys* 679 139-144

[26] Zhao L, Ling L-L and Zheng Z-M 2016 *ZooKeys* 582 111-120

[27] Robillard T and Tan M K 2013 *Raffles Bull. Zool.* 61 705-725

[28] Banerjee S K and Kevan D K 1960 *Trubia* 25 165-189

[29] Ahmad A T and Tajaral M 2014 *Rep. Opin.* 6 44-48

[30] Badruddin, S M A 2004 Ecological studies on some gregarious acridoids of agricultural importance in North India Thesis Faculty of Life Science Aligarh Muslim University: Aligarh

[31] Lewis A C and Barnays E A 1985 *Entomol. Exp. Appl.* 37 105–112.

[32] Kočárek P, Holuša J, Grucmanová Š, and Musiolek D 2011 *Open Life Sci.* 6(4) 531-544.

[33] Latupapua M J 2011 *J. Agroforestri, VI (2)* in Indonesia.

[34] Alexander G 1951 *Ecol.* 32 104-12

[35] Nahlunnisa H, Zuhud E A and Santosa Y 2016 *Media Konserv.* 21 91-98 in Indonesia.