Al-Hayat: Journal of Biology and Applied Biology
Volume 6, No 2 (2023): 159-170
DOI. 10.21580/ah.v6i2.17767

Effect of *Asilidae* on Decreasing Locust Population as a Pest in Agricultural Ecosystems

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Abstract

Pathogenic insects, such as *Asilidae* or robber flies, can prey on other insects, leading to a decline in their populations, particularly grasshoppers. The reduction in grasshopper population has a positive impact on the agricultural ecosystem. However, the fauna diversity in such an ecosystem is comparatively lower than in plantation forests. One such fauna species found in agricultural ecosystems is the grasshopper. Large numbers of locusts can cause significant losses in agricultural yields. Therefore, this research aimed to investigate the influence of *Asilidae* on the decline of grasshopper populations in agricultural ecosystems. The research methodology employed a meta-analysis approach, incorporating relevant theories and referencing five accredited articles. In this context, meta-analysis is a quantitative technique that utilizes specific data to derive informative conclusions. The results of this study revealed that flies, characterized by their size ranging from small to very large (body length: 4-65 mm; wing length: 4-40 mm), were predatory, preying on other insects while in flight. Accordingly, the findings from previously conducted research demonstrated a clear influence of *Asilidae* on the reduction of grasshopper populations in agricultural ecosystems.

Keywords: *Asilidae*, locust, decomposer, ecosystem

Introduction

Grasshoppers are a class of insects in the order *Orthoptera*, comprising 20,000 species (Prakoso, 2017). While some grasshoppers are herbivores, others serve as decomposers and feed on other insects. In agricultural settings, they are known to be plant-eating animals or herbivores, often causing damage to cereal and vegetable crops. In Indonesia, locusts are particularly problematic pests, causing significant harm to corn crops (Adnan, 2009).

Various types of insects are commonly found in agricultural areas, and More and Nikam (2016) have documented that millions of locusts congregate in large numbers, leading to crop damage. They can also indicate field quality due to their widespread presence in substantial quantities across the land. Rowell (1987) suggests that while locusts are found in all types of areas, certain species inhabit forest ecosystems. Likewise, Probe and Scalpel (1980) argue that grasshoppers feed on wild and cultivated plants.

Forest are important ecosystems that support diverse forms of life. Hartley (2002) explains that forests undergo long-term modifications, impacting the climate and resulting in different undergrowth components than natural forests. Modified forest, also known as plantation forests, are

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predominantly filled and planted with industrial crops to meet industrial raw material demands. According to Altieri (1999), this circumstance creates an agroecosystem that simplifies biodiversity into monocultures, requiring constant treatment by applying chemical or organic fertilizers and pesticides.

Chemical pesticides are no longer considered the appropriate solution for controlling plant diseases caused by pests due to their negative impacts, including environmental pollution of soil and water from chemical residues, as well as the presence of pesticide residues in harvested food crops. Moreover, the continuous exposure of pathogenic pests to pesticides has resulted in the development of immunity, hindering and destroying parasitoid insects and predator populations.

Research conducted by Moningka et al. (2012) discovered that excessive pesticide use and forest development were ineffective in protecting natural enemies. Instead, they caused environmental damage and resulted in the eradication of these natural enemies. One way to naturally control pests is by harnessing the enemies' potential. Natural enemies can effectively regulate pest populations if the surrounding environment allows them to thrive. In Indonesia, agricultural ecosystems host a variety of enemies that can reduce the presence of pathogenic pests.

Integrated pest management (IPM) has been widely adopted in agricultural ecosystems to limit farmers' reliance on chemical pesticides. A key component of IPM is utilizing biological control techniques, which involve using predators, pathogens, and parasitoids to control pests. Insects pose a significant threat to ecosystems, particularly in agricultural settings. Biological control serves as a means to manage natural enemies by leveraging the potential of predators, pathogens, and parasitoids. While certain species provide benefits, such as predators and parasitoids that aid in pollination and decomposition of organic matter, pest insects can cause extensive damage to agricultural land, resulting in significant crop losses.

The use of parasitoids as a strategy for pest control is an alternative method currently being developed to reduce reliance on pesticides (Kojong et al., 2015). Parasitoids are natural enemies capable of regulating pest populations in their natural environment. They are crucial in biological pest control and have been successfully applied. Parasitoid insects reproduce within the bodies of their hosts and can consume eggs, larvae, or adult insects. One such parasitoid that contributes to pest control is the *Asilidae*.

Robber flies, also known as *Asilidae*, are one of the most prominent families within the order *Diptera*, comprising approximately 7,500 species (Dikow et al., 2017). These flies vary in size, ranging from 5 to 60 mm. They possess a distinctive body shape, typically an elongated cylindrical abdomen and various sclerite colorations, often covered with thick hairs. Representative members of this family can be found in diverse habitats, with the highest species diversity observed in arid, semi-arid, and tropical forests.

Diptera, *Coleoptera*, *Hymenoptera*, and *Hemiptera* are among the largest animal orders worldwide, even when considering regional fauna. However, numerous species from these orders have become endangered in recent years, and several families have been listed as endangered (Ruchin et al., 2019).

Despite their significance, the *Diptera* family remains relatively understudied. Limited information is available regarding the Mordovian fauna of *Tipulidae* and *Limoniidae* (Pilipenko et al., 2020; Budaeva & Ruchin, 2016). Adult flies and their larvae, being active predators, play a crucial role in the ecosystem (Astakhov, 2015; More & Nikam, 2016). Moreover, robber flies can inhabit a wide range of terrestrial ecosystems.

Insects exhibit variations in their abundance within different locations, which can be attributed to their reproductive capabilities and ability to adapt to suitable habitats. The stability of agricultural ecosystems can be assessed through ecological pyramids and the interrelationships among community components, such as pests/herbivores, predators, and parasites/carnivores (Untung, 2006). Therefore, it is essential to comprehend the role of *Asilidae* in reducing locust populations within agricultural ecosystems.

Research Method

This research was conducted employing a meta-analysis approach, incorporating relevant theoretical references. In this regard, meta-analysis is a method that involves combining, reviewing, and summarizing the results of multiple studies in order to obtain comprehensive findings. For this analysis, the results of previous studies on the same topic are reviewed (Palmam, 2015).

This study utilized national and international articles examining the impact of *Asilidae* on reducing locust populations as agricultural pests within ecosystems. The objective was to determine the effect of *Asilidae* on the decline of locust populations in agricultural ecosystems. Hence, multiple articles were selected as research samples.

Observations of grasshopper species were conducted in a research laboratory based on several accredited articles to identify the role of grasshoppers and to identify specific specimens (Borror et al., 1996). According to Catling et al. (2020) and several other studies, the role of grasshoppers in the ecosystem can be assessed by analyzing images of plants taken from the same plot position, followed by temperature, humidity, altitude, and wind speed measurements.

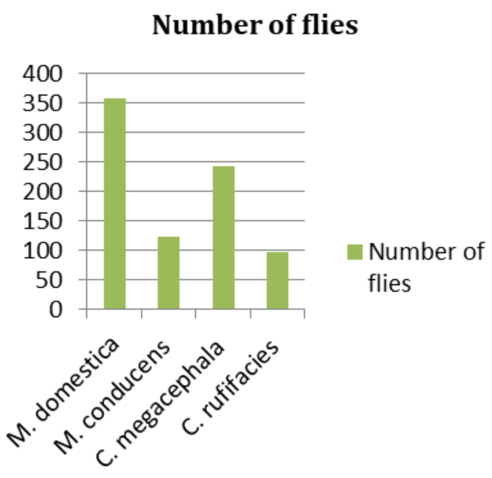
Research Results and Discussion

Based on the search results of national and international articles in scientific publications published betweeb 2017 and 2022 that met the specified criteria, the findings are presented in Table 1. The analysis identified a total of 3,097 *Orthoptera* individuals belonging to the *Acrididae*, *Pyrgomorphidae*, and *Tetrigidae* families, encompassing 7 genera: *Oxya*, *Gesunola*, *Criotettix*, *Atractomorpha*, *Valanga*, *Miramella*, and 7 other species. 3 species were observed within the agricultural ecosystem, while the plantation forest ecosystem exhibited 5 species.

Table 1. Findings of Fly and Locust Species in Agricultural Ecosystems and Plantation Forests

No	Species	Article Title	Total
1	*Musca domestica*, *Musca conducens*, *Chrysomya megacephala*, and *Chrysomya rufifacies*	*Kelimpahan Nisbi, Frekuensi, dan Dominansi Jenis Lalat di Beberapa Pasar Tradisional di Kecamatan Martapura*	823
2	*Atractomorpha crenulata*, *Criotettix robustus* (Hancock), *Gesonula mundata* (Walker), *Hesperotettix viridis pratensis*, *Miramella alpina*, *Oxya hyla intricata* (Stal), *Valanga nigricornis* (Burmeister)	*Biodiversitas Belalang (Acrididae: Ordo Orthoptera) pada Agroekosistem (Zea mays L.) dan Ekosistem Hutan Tanaman di Kebun Raya Baturaden, Banyumas*	1030

Table 1 comprises the results of several studies, indicating the presence of various species in different quantities. They included *Musca domestica* (359 individuals), *Musca conducens* (124 individuals), *Chrysomya megacephala* (242 individuals), and *Chrysomya rufifacies* (98 individuals). These results are consistent with Suraini (2011), highlighting that *Musca domestica* and *Chrysomya megacephala* were the most commonly found fly species in community environments, such as traditional markets. The following graphic provides a visual representation of these findings.



Other studies focusing on agricultural ecosystems (specifically *Zea mays L.*) reported the presence of species such as *Valanga nigricornis* (Burmeister), *Gesonula mundata* (Walker), and *Oxya hyla intricata* (Stal). In plantation forest ecosystems, the identified species included *Oxya hyla intricata* (Stal), *Atractomorpha crenulata*, *Criotettix robustus* (Hancock), *Hesperotettix viridis pratensis*, and *Miramella alpina* (Kollar). The agricultural ecosystem exhibited 1030 individuals, representing 1 family and 3 species. On the other hand, the plantation forest ecosystem recorded 2067 individuals, encompassing 3 families and 5 species. These findings demonstrated that plantation forest ecosystems harbored a greater species diversity than agricultural ecosystems.

The data collected indicates a higher abundance of insect species in plantation forests than in agricultural ecosystems. This situation could be attributed to the broader variety of flora present in plantation forests as compared to agricultural environments. The vegetation structure in both ecosystems influenced the diversity of grasshoppers species. Insects rely on the availability of suitable habitats and food sources, which are more abundant in natural forests due to the diverse range of vegetation (Lachat et al., 2006).

Several factors affected the diversity of grasshoppers in ecosystems, including environments. Research results from several articles accredited by SINTA have revealed that agricultural areas have an average temperature of 32.16ºC, ranging from 28ºC to 39ºC. In contrast, plantation forest ecosystems have an average temperature of 23ºC, with a minimum of 21ºC and a maximum of 26ºC.

A study conducted by Pudjiharta (2010) at the Baturaden Botanical Garden in Dammar Forest reported a temperature range of 19.5ºC to 21.4ºC. Fajarwati et al. (2009) investigated tomatoes in agricultural ecosystems. They found a temperature range of 14ºC to 26ºC, indicating a temperature increase of 10ºC compared to the plantation forest ecosystem, which only experienced a 2ºC increase.

The research on agricultural ecosystems demonstrated an average humidity of 60%, ranging from 46% to 81%. Plantation forests, on the other hand, exhibited an average humidity of 77.6%, ranging from 69% to 98%. Pudjiharta (2010) also reported a humidity range of 87.5% to 93.2% in dammar forests, while Fajarwati et al. (2009) found a humidity of 81.4% in agricultural ecosystems. Thus, there was a significant decline of 10% in humidity in agricultural ecosystems compared to plantation forest ecosystems, which experienced a decline of only 5%.

A temperature change of approximately 1°C affects evapotranspiration by 2% to 3%, while a humidity change of 5% impacts evapotranspiration by 9% (Mock, 1973). Accordingly, Haneda et al. (2013) argue that increasing temperature changes influence the geographical distribution, insect activity, reproduction, and fluid evaporation in the insect's body.

Temperature and humidity are among several factors that influence insect diversity, as evidenced by samples taken over an extended period in different seasons. (Noor, 2008), as cited in (Tofani, 2008), states that during the dry season, the soil surface will be populated by many families of *Formicidae* and *Nitidulidae*. In contrast, the rainy season will increase the number of *Formicidae* and *Tenebrionidae* families.

Furthermore, the diversity of grasshoppers is influenced not only by vegetation and environmental structures but also by biological factors such as parasitoids, predators, and entomopathogens. Accordingly, research conducted by Susniahti et al. (2005) indicates that the grasshopper population decreases when those factors are present in higher quantities. This finding underscores the significant impact of these factors on grasshopper populations.

Fajarwati et al. (2009) argue that insect diversity varies in different ecosystems. This variation can be attributed to several factors, including insect behavior such as feeding habits, lifestyle, reproduction, climate, food availability, geographical conditions, altitude, temperature differences, and other environmental factors such as geology and ecology. (Tofani, 2008) further suggests that the ability of insects to disperse, their preference for light and weather conditions, habitat selection, and the availability of food and plants also contribute to their diversity.

In a research conducted in India in 1997, the order *Orthoptera* was found to consist of 50 species in the paddy field ecosystem. They included the families of *Tettiigonidae* (8 species), characterized by long antennae, *Acrididae* and *Pyrgomorphidae* (28 species), characterized by short antennae, crickets (3 species), and tree cricket (1 species). Additionally, 10 species from the family *Tetrigidae* were identified (Chitra et al., 2000). (Erawati & Kahono, 2010) reported the discovery of 414 individual locusts, comprising 5 families and 25 species, in Mount Kendeng and Mount Botol.

Similar findings were observed by (Akthar et al, 2012) in paddy field ecosystems and a study conducted in Uttar Pradesh City, India, from 2010 to 2011 by Rabi and Kharif. These investigations revealed abundant diversity within the families of *Acrididae* and *Pyrgomorphidae*. The availability of grass as a food source contributed to this abundance, particularly for the *Acrididae* subfamilies like *Oxyinae* and *Truxalinae* (Das & Ray, 2013).

Regarding species abundance, *Gesonula mundata* (Walker) was found to be the most abundant species in the agricultural ecosystem, with a total of 807 individuals. In contrast, *Hesperotettix viridis pratensis* was the most abundant species in the plantation forest ecosystem, with 1,199 individuals. Both environments also contained *Oxya hyla intricata* (Stal) species, with 9 individuals in the agricultural ecosystem and 456 in the plantation forests.

In the agricultural ecosystem, there were 213 individuals of *V. nigricornis*. Sofyan (2010) mentions that *V. Nigricornis*, also known as the wood locust, possesses distinctive characteristics in its antennae, body, wings, and legs. Specifically, the antennae are short, the body length measures 6.2 cm, the front wings are straight and slightly rigid, and the rear wings take the form of membranes. Moreover, the front legs are thicker and shorter than the hind legs. Both nymphs and adult wood locusts are approximately 44-72 mm long and display a light yellowish-green coloration (Kalshoven, 1981).

According to Sofyan (2010), *V. nigricornis* is known to feed on various plants, making it a phytophagous insect. If left uncontrolled, it can cause damage to plants and has the potential to become a pest. However, it was noteworthy that *V. nigricornis* was not a significant pest on crops in Malaysia, although it could still threaten new crops and seedlings (Lee, 2014).

Another study conducted by Leatemia & Rumthe (2011) reported the presence of *V. nigricornis* in the village of Jakarta Baru and in corn plantations at UPT-Y. In the Bula District, the damage caused by *V. nigricornis* to corn plants was categorized as mild, accounting for 10.65% of the total damage. The attack of *V. nigricornis* left bite marks around the edges, leading to the hollowness of the leaves.

Agricultural ecosystems and plantation forests share a species similarity indicator of 0.25 or 25%. Das and Ray (2013) identified *O. hyla* as a species in both ecosystems. It belongs to the *Poaceae* family and has a preference for grasses. As a result, *O. hyla* is more commonly found in plantation forests than agricultural ecosystems.

Research findings strongly indicated that locusts caused significant losses to agricultural products. However, parasitoids could effectively reduce their population in agricultural areas, preventing damage to agricultural products, gardens, and other green spaces. By consuming plant leaves, locusts often leave distinct holes in garden areas.

Table 2. Recapitulation of the Results of the Influence of *Asilidae* Insects

No	Article Title	Author(s)	Year
1.	To Robber Flies Fauna (Diptera: *Asilidae*) of Mordovia, Russia	Dmitry M. Astakhov, Alexander B. Ruchin, Olga D. Romadina, and Ivan M. Pristrem	2019
2.	*Serangga Predator pada Ekosistem Padi Sawah di Kecamatan Tombatu, Kabupaten Minahasa Tenggara*	Herianto I. Kojong, Moulwy F., and Noni N. Wanta	2014
3.	*Identifikasi Predator Tanaman Padi (Oryza sativa) pada Lahan yang Diaplikasikan dengan Pestisida Sintetik*	Fitriani	2018
4.	*Keanekaragaman Serangga Parasitoid untuk Pengendalian Hama pada Tanaman Kehutanan*	Yeni Nuraeni, Illa Anggraeni, and Wida Darwiati	2017
5.	Robber Flies, *Asilidae* (Insecta: *Diptera*: *Asilidae*)	E. M. Finn	1969
6.	*Keanekaragaman Jenis Belalang (Ordo Orthoptera) di Pertanian Kacang Hijau (Vigna radiata L.) Desa Manusak Kabupaten Kupang*	Chatarina Gradict Semiun and Yulita Iryani Mamulak	2019

Species of the order *Orthoptera* play a significant role as plant eaters in agricultural ecosystems and plantation forests. The plant-eating families of *Orthoptera* found in these environments included *Acrididae*, *Pyrgomorphidae*, and *Tetrigidae*. Based on observations, locusts were found in various plant species such as *Ageratina riparia (Regel) R.M.King & H.Rob*, *Ageratum sp., Impatiens platypetala (Lindl)*, *Kyllinga sp.*, *Polytrias sp.*, *Thelypteris sp.*, among others, in plantation forests. In agricultural ecosystems, locusts were observed to cause damage to corn leaves. This finding was supported by Ullah (2012), who discovered that grasshoppers belonging to the order *Orthoptera: Acrididae* were essential plant eaters in the prairies of the western United States.

In the agricultural ecosystem, the predominant insect species belonging to the *Acrididae* family, like *Tetrigidae* and *Pyrgomorphidae*, were found in plantation forests. Generally, plant-eating grasshoppers are classified under the *Acrididae* family. However, it is important to note that while they were found in agricultural ecosystems and plantation forests, they exhibited different feeding preferences. Besides, the families of *Tetrigidae* and *Pyrgomorphidae* were absent in the agricultural ecosystem.

Parasitoids are insects that play a crucial role in biological control. They live inside their host's body during various life cycle stages and can consume eggs, larvae, and adult/imago insects. The presence of parasitoids can help reduce the population of locust species in agricultural areas.

Therefore, robber flies, or *Asilidae*, are used as parasitoids. Flies, belonging to the order *Diptera*, are an insect commonly found near humans. Likewise, families such as *Calliphoridae*, *Muscidae*, and *Sarcophagidae* also live close to humans (Susrama, 2018).

Currently, the Mordovia State Nature Reserve only has one species of robber fly in its fauna, namely *Laphria gibbosa*. However, a total of 13 species from the *Asilidae* family have been identified in the Mordovia State Nature Reserve, including *Leptogaster cylindrica*, *Dioctria cothurnata*, *Lasiopogon cinctus*, *Laphria marginata*, *Laphria gibbosa*, *Choerades gilva*, *Choerades fuliginosa*, *Andrenosoma atra*, *Asilus crabroniformis*, *Machimus rusticus*, *Neoitamus cyanurus*, *Tolmerus atricapillus*, and *Echthistus rufinervis*.

Several species of *Asilidae* have also been identified, including *Dioctria oelandica*, *Didysmachus picipes*, *Tolmerus atricapillus*, and *Pamponerus germanicus*.

Conclusion

Based on the findings of the meta-analysis, it can be concluded that a diverse range of grasshopper families, species, and individuals belonging to the *Orthoptera Order: Acrididae* exist in plantation forest ecosystems. Specifically, the study identified 2096 individuals representing 5 species and 3 families in plantation forests, which differed significantly from agricultural ecosystems where only 1029 individuals from 3 species and 1 family were observed. The investigation further explored the influence of habitat types and elevations on grasshopper populations in natural forests, plantation forests, and agricultural ecosystems to assess their potential as pests with detrimental impacts on humans. The meta-analysis of the collected articles revealed a significant impact of *Asilidae* on the decline of grasshopper populations as agricultural pests. Likewise, this research aimed to investigate the influence of parasitoids, particularly *Asilidae*, on grasshopper populations and their implications for agricultural ecosystems.

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