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To cite this article: M Syahrawati *et al* 2021 *IOP Conf. Ser.: Earth Environ. Sci.* **741** 012013

Predation of *Phidippus* sp (Araneae: Salticidae) on *Nilaparvata lugens* (Hemiptera: Delphacidae) at different densities

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Abstract. *Phidippus* sp. (Araneae: Salticidae) is often found in rice field and has potency as the natural enemy of *Nilaparvata lugens* (Hemiptera: Delphacidae). The study aimed to know the predation of *Phidippus* sp on *N. lugens* in laboratory. The study used a Completely Randomized Design consisting of five treatments and five replications. The treatments were the difference of *N. lugens* densities of 10, 20, 30, 40, and 50. *Phidippus* sp was collected from rice fields around Padang City, while *N. lugens* used was 2nd-3rd instar of nymphs reared in laboratory. The results showed that *Phidippus* sp has potency for controlling the BPH population. The predation tended to increase with increasing *N. lugens* density, but the percentage of predation and weight gain decreased. *Phidippus* sp was able to consume prey provided to a maximum of 96.0%. The increasing density shortened the time needed by *Phidippus* sp to find prey. The shortest time to find the first prey and the highest number of predation occurred at 50 individuals of *N.lugens* provided (1.99 minutes for 28.2 individuals preyed) but in lowest percentage of predation and weight gain (56.4% and 0.0004 g/ day respectively). The functional response of *Phidippus* sp was logarithmic with a weak to strong correlation (r = 0.515).

Keywords: Brown planthopper, finding time, functional response, handling time, prey consumption

1. Introduction
Some efforts to increase rice production in several places in the world are faced with various obstacles, including by brown planthopper (BPH) attacks (*Nilaparvata lugens* Stal 1854, Hemiptera: Delphacidae). This insect damages by sucking saps of rice plants, so the plants become wither and dry up as if burned-like. Furthermore, BPH also acts as a vector for rice grassy stunt virus and rice ragged stunt virus that can cause crop failure or hopperburn [1][2]. For preventing the negative impact of BPH attack on the safety of rice production, various technologies have been applied in the field, including the use of resistant varieties, synthetic insecticides, cultivation methods (such as planting time, simultaneous planting, irrigation) and the use of natural enemies. Synthetic insecticides are still the primary choice of farmers to apply due to very effective in suppressing the BPH population but not safe to the ecosystem. Environmentally-friendly control can be done in several ways; one of them is utilizing natural enemies such as spiders.

Spiders (Araneae) are generally predators of pest insects found in rice field [3]. There are many spider families found in the rice ecosystem, namely Lycosidae, Linyphiidae, Oxyopidae, Tetraghnatidae, Thomisidae, and Salticidae [4], and found 29 species of natural enemies, including *P.*

pseudoannulata (Lycosidae) and *Phidippus* sp. (Salticidae) [5]. There are 6 families, 7 genera and 10 species of spiders found in lowland rice in North Aceh Regency, Indonesia, one of the species is *Phidippus* sp [6]. Then, the presence of *Phidippus* sp also found in rice field [7].

Many researchers have widely reported information about *P. pseudoannulata* ability to suppress the BPH population. *P. pseudoannulata* can prey of 5-24 individuals BPH/ day [8][9][10][11]. The optimum of *P. pseudoannulata* ability to prey is 15 individuals of BPH/day [12]. So far, there has been no report regarding the predation of *Phidippus* sp on BPH as like as *P.pseudoannulata*. *Phidippus* sp was reported can prey on smaller insects or to soft-bodied [13], even flying insects such as dragonfly, cockroach, grasshopper and cicada [14], house cricket [15], other spiders [16], and also vertebrate [17]. This study aimed to know about the potency of *Phidippus* sp as a biocontrol agent of BPH at different densities.

2. Material and methods

2.1 Phidippus sp. collection

Phidippus sp. were collected directly from rice field in Pauh District, Padang, West Sumatera. Those predators were put into a plastic cup separately one by one to avoid cannibalism and fed with three to five nymphs of *N. lugens*. The number of prey was added each time the prey was consumed up. After one week, predators were starved for 24 hours before use. There were 25 individuals of *Phidippus* sp of the same size provided for all treatments and replications.

2.2 N. lugens rearing

N. lugens was reared at the laboratory since October 2017 in Cisokan variety of rice. The seeds are soaked for 24 hours and then air-dried for ± 1 hour and transferred to a culture jar (volume = 25 liters) containing water as high as 2 mm. The water height was maintained in that position where can cover the seeds as a whole. Five to seven days after sowing, ten pairs of *N. lugens* adults were put into culture jar. Seven to ten days later, the first instar of nymph emerged. The total of nymphs used in this study were second to the third instar as much as 750 individuals.

2.3. Treatment

The research was conducted at Laboratory of Insect Bioecology, Faculty of Agriculture, Universitas Andalas, during May-July 2019. The research was carried out using a Completely Randomized Design consisting of five treatments and five replications. The treatment was the predation of one *Phidippus* sp. at different densities of N. *lugens* (10, 20, 30, 40, and 50 individuals). The average minimum and maximum temperatures daily were 26.7°C and 29.2°C respectively, while the average minimum and maximum relative humidity daily were 70.6% and 80.9%, respectively.

Two plastic cups with a volume of 360 ml were provided for each replication. One cup was perforated at the bottom using a hot nail with a diameter of about 2 mm. Three rice seedlings aged seven days after sowing were put into the cup through a hole that has been made before, while the roots were positioned outside the cup. The second cup was filled by water with a high of 2 mm and placed overlapping with the first cup and used as roots growth media. After that, the nymphs of *N. lugens* were put into the cup according to treatment. *Phidippus* sp, which has been starved for 1 × 24 hours and weighed its body firstly before use for treatment using analytical scales with a precision of 4 decimal.

2.4. Predation and predation increase

The number of *N.lugens* consumed by *Phidippus* sp was carried out by counting the number of *N. lugens* consumed for 3x24 hours. Then the percentage of predation and predation increase on second and third day were measured using the following formula:

$$\text{Predation} = \frac{\text{number of } N.lugens \text{ consumed}}{\text{number of } N.lugens \text{ provided}} \text{ x } 100$$

$$\text{Increase} \;\; = \frac{N.lugens \text{ consumed on previous day} - \; N.lugens \text{ consumed on that day}}{N.lugens \text{ consumed on that day}}$$

2.5. Finding time, handling time, and predation rate

Finding time was the time spent by a predator to find prey, started from being put into a plastic cup until finding its prey. Handling time was the time spent by a predator in handling its prey during the first 60 minutes. While the predation rate was calculated using the following formula [18][19]:

$Na = \frac{aTN}{1+aThN}$ or $a = \frac{Na + a.Na.Th.N}{TN}$

Na = number of prey consumed
a = predation rate
T = predation time provided (60 minutes)
N = prey density
Th = time spent by a predator to handling one prey

2.6. Bodyweight (g)

The weight of a predator was measured by weighing it using analytical scales with a precision of 4 decimals. Predator body weight gain was obtained by measuring the difference in body weight on the first day to the third day against body weight before treatment.

2.7. Functional response

The predatory functional response was the ability of the predator to consume prey, which was influenced by prey density, finding, and handling time. Holling introduced three types of functional responses, namely types I, II, and III. Type I is characterized by an increase in predation rate along with an increase in prey density to a specific predation rate becomes constant due to predation satiation (Linear). Type II is characterized by slow predation at the beginning due to the learning time process followed by an increase in predation until predation satiation (Exponential). Type III is characterized by predation increase at the beginning and followed by slow predation (Logarithmic) [18][20].

The regression equation was determined through regression analysis using the software of SPSS 16. The type of functional response was determined through the highest r score that revealed a close correlation between predation rate and prey density. The correlation was stated positive and strong if r score going to 1, negative and strong if r score going to -1 and weak if r score going to 0.

2.8. Analysis of data

The data obtained from the predation of *Phidippus* sp, finding time, handling time, predation rate, and body weight gain were analyzed by ANOVA and LSD test at a 5% significance level using the software of Statistix 8.

3. Results and Discussion

3.1. The predation (24 hours)

The predation of *Phidippus* sp for 24 hours tended to increase with increasing density of *N.lugens* but followed by decreasing the percentage of predation. The highest number *N.lugens* consumed by *Phidippus* sp at a density of 50 individuals (consumed 28.2 individuals) but only consumed 56.4% of the total prey provided. The highest percentage of predation occurred at the density of 10 individuals (90%) (Table 1).

Table 1. The predation of *Phidippus* sp on different densities of *N.lugens*

N.lugens density (individuals)	Predation	
	Number (individuals)	%
10	9.0 b	90.0 a
20	13.4 b	67.0 ab
30	23.6 a	78.7 ab
40	26.4 a	66.0 b
50	28.2 a	56.4 b

Note: The number followed by small letter is significantly different according to LSD test at 5% significance level

3.2. The predation during 3 days

Phidippus sp was able to prey to a maximum of 96% of *N.lugens* provided during 3 days. Predation on the first day ranged from 56.4-90.0%, with the highest predation occurred at a density of 10 individuals. On the second day, there was an increase in predation between 6.0-21.2%, while on the third day, there was an increase in predation of 0.0-8.8%. The highest increase in predation on the second and the third days occurred at a density of 50 individuals, at the same density became the lowest predation occurred on the first day. Until the third day, *Phidippus* sp still left the prey even at the lowest density (10 individuals) (Table 2).

Table 2. Cumulative predation (%) of *Phidippus* sp. at different densities of *N.lugens* and the predation increase during 3 days (inserted below)

Density	Predation (%)			Predation increase (%)	
	1 day	2 days	3 days	2nd day	3rd day
10	90.0	96.0	96.0	6.0	0
20	67.0	81.0	89.0	14.0	8.0
30	78.7	88.0	94.0	9.3	6.0
40	66.0	81.5	87.5	15.5	6.0
50	56.4	77.6	86.4	21.2	8.8

3.3. Finding time, handling time and predation rate

Increasing prey density tended to shorten the time needed by *Phidippus* sp to find the prey. The shortest time to find the first prey was at 50 individuals densities (1.99 minutes), but it was not significantly different in the densities of 30 and 40 individuals but significantly different in the densities of 10 and 20 individuals of *N.lugens*. The handling time and the predation rate of *Phidippus* sp were apparently not affected by prey density (Table 3).

Table 3. The time needed by *Phidippus* sp to consume *N.lugens* at different densities and the predation rate

N.lugens density (individuals)	Finding time (minutes)	Handling time (minutes)	Predation Rate (60 minutes)
10	29.12 a	9.88 a	0.0115 a
20	9.58 b	9.98 a	0.0137 a
30	3.86 bc	4.60 a	0.0019 a
40	3.24 c	7.75 a	0.0070 a
50	1.99 c	7.82 a	0.0026 a

Note: The number followed by small letter is significantly different according to LSD test at 5% significance level

3.4. Bodyweight gain (g/day)

The bodyweight of *Phidippus* sp before and after treated with different densities of *N.lugens* showed no difference significantly, but the increase in body weight tended to decrease with increasing density. The lowest increase occurred at a density of 50 individuals density (0.0004 g). That condition was not significantly different from the increase of body weight at a density of 40 individuals but significantly different from a density of 10-30 individuals (Table 4).

Tabel 4. Bodyweight of *Phidippus* sp. when consuming *N.lugens* at different densities

N. lugens density (individuals)	Bodyweight (g/day)		
	before	after	Increase
10	0.0103 a	0.0121 a	0.0047 a
20	0.0108 a	0.0132 a	0.0038 ab
30	0.0099 a	0.0128 a	0.0034 ab
40	0.0102 a	0.0136 a	0.0024 bc
50	0.0108 a	0.0144 a	0.0004 c

Note: The number followed by small letter is significantly different according to LSD test at 5% significance level

3.5. *Functional response*

Based on the r scores, it can be seen that the functional response type of *Phidippus* sp to *N. lugens* was classified as Logarithmic (Type III) with equation $Y = 2.233 \times X^{-2,639}$. It meant that *Phidippus* sp showed an increase of predation at the beginning and followed by slow predation. The correlation between the predation rate of *Phidippus* sp and the number of *N.lugens* consumed was weak (r = 0.515) (Table 5, Figure 1).

Tabel 5. Functional response type of *Phidippus* sp. at different densities of *N.lugens* based on regression analysis and r scores

Type	Regression	r	Equation
I	Linear	0.459	$Y = 0.08 + 2.24x$
II	Eksponential	0.427	$Y = 0.20 \times 2.143^{X}$
III	Logarithmic	0.515	$Y = 2.233 \times X^{-2.639}$

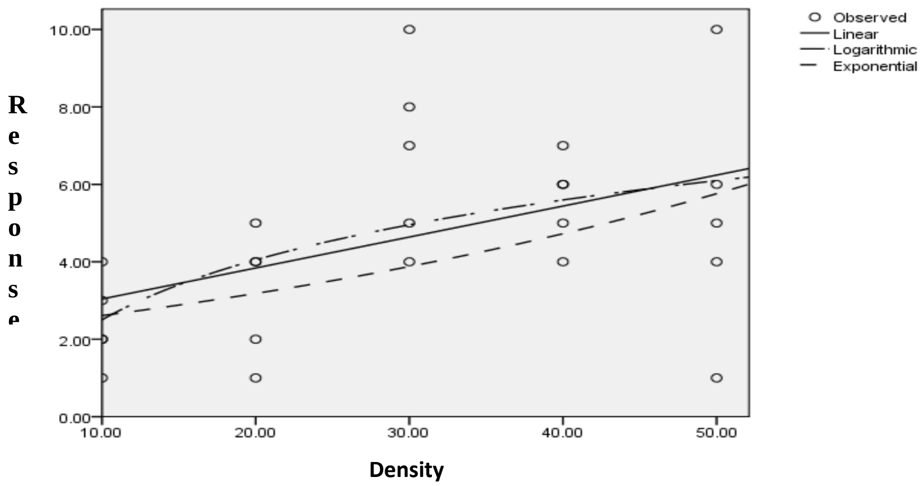

Figure 1. The predation and functional response of *Phidippus* sp. at different densities of *N.lugens*

Phidippus sp has the potency to suppress *N. lugens* populations in the field. Based on the research, the predation increased with increasing density of *N. lugens*, but the percentage of predation and weight gain actually decreased, particularly on the first day. *Phidippus* sp was able to consume up to a maximum of 96.0% of the prey provided for 3 days, and the highest predation occurred on the first day. On the first day, the percentage of predation tended to decrease when the prey density increased.

On the second and the third days, the increase in density did not affect the percentage of predation anymore (Table 1, Table 2). A factor of predation satiation probably caused that condition. The predation ability was limited by the needs [21]. When predator was flooded with potential prey or outbreak population of prey happening in the field, the predator consumed only a certain number. The predation rate tended to decrease with increasing prey density, due to increased predation satiation in higher prey densities[22][23][24]. The differences in predation rate and time of predation are caused by variations in prey size, moving speed, voracity, starvation, digestibility, and satiation [25].

The highest percentage of predation occurred at a density of 10 individuals of *N.lugens* for 3 days observation (90-96%), it was estimated that the optimal ability of *Phidippus* sp. in preying *N.lugens*. Actually, the predation number of *Phidippus* sp was lower than *P.pseudoannulata* where the highest percentage of predation could be obtained at a density of 15 individuals of *N. lugens* (86%) [12]. The availability of prey from low density to high did not cause *Phidippus* sp to consume all prey, even though the availability of prey decreased on the second and the third days. It was related to a habit some predator of not eating prey at all. Some literature [26][12] stated that predator has the behavior to protect their prey when there is no other choice of prey.

The increasing density of *N. lugens* only shortened the time needed by *Phidippus* sp to find prey, but it did not affect the handling time and predation rate. The shortest time to find the first prey and the highest number of predations occurred at 50 individuals of *N. lugens* (1.99 minutes for 28.2 individuals prey) (Table 3, Table 1) but with the lowest percentage of predation and weight gain (56.4% and 0.0004 g/day respectively (Table 1 and Table 4). The more prey available, the less time was needed to search and find prey. Increasing the density of prey determines efficiency in searching and handling prey by the predator [26].

On the contrary, increasing the density of *N. lugens* did not affect the handling time and predation rate and tended to decrease the bodyweight of *Phidippus* sp. (Table 4). Its behavior could influence that. *Phidippus* sp. relatively slow in finding and handling prey. When meeting with the prospective prey, it did not immediately aggressively catch it but circled first, approaching slowly, and then catching it. The captured prey was brought first to a safe place (the top of the cup) and then handled by sucking its body fluids. After consuming, *Phidippus* sp spent much time resting at the top. The behavior was assumed to have wasted its time and energy, but *P.pseudoannulata* is very aggressive in preying [12]. The predation rate connected directly to weight gain. The weight gain increases when the predation rate increases. Spiders could prey equal to 12% of their body weight [28]. The density of 3 species of prey does not affect the predation rate of *Menochilus sexmaculatus* [29]. This statement was reinforced by [30][31], that the predation rate of *Verania lineata* and *M.sexmaculatus* did not show a significant effect on different densities of *N. lugens*. It was presumed happening due to differences in the behavior of predators in handling prey.

Functional response is one indicator to determine the effectiveness of a predator in controlling prey populations. Functional response is influenced by many factors such as temperature [32][33], plant growth phase, prey stage [34], alternative prey [35], environmental factors, habitat complexity and predator condition [36], and also the size and density of prey and predator [37][38]. The type of functional response shown by predators plays an important role in the stability of the prey population.

The functional response of *Phidippus* sp. was type III or logarithmic, and the correlation between density and number of prey classified as weak to strong (r = 0.515) (Table 5, Figure 1). It showed that the predation of *Phidippus* sp. increased at the beginning, then continued to slow predation, but at specific *N.lugens* density, the response of *Phidippus* sp. decreased and then constant. In general, Type III has a similarity with Type II. The difference was seen in the fast and slow response at the beginning of predation. Meanwhile, the functional response of *Neoscona theisi* (Araneae: Aranidae) and *Oxyopes javanus* (Araneidae: Oxyopidae) to *Sogatella furcifera* (Hemiptera: Delphacidae) was Type II (Exponential) [39][40]. The increasing density of *N. lugens* only shortened the time needed by *Phidippus* sp to find prey, but it did not affect the handling time and predation rate. The shortest time to find the first prey and the highest number of predations occurred at 50 individuals of *N.*

lugens (1.99 minutes for 28.2 individuals prey) (Table 3, Table 1) but with the lowest percentage of predation and weight gain (56.4% and 0.0004 g/day respectively (Table 1 and Table 4). The more prey available, the less time will be needed to search and find prey. According to [27], increasing the density of prey determines efficiency in searching and handling prey by the predator.

4. Conclusion

Phidippus sp has a potency for controlling the BPH population in the field. The predation tended to increase with increasing *Nilaparvata lugens* density, but the percentage of predation and weight gain actually decreased. *Phidippus* sp could prey to a maximum of 96.0% of the prey provided for 3 days. The increasing density of *N. lugens* shortened the time needed by *Phidippus* sp to find prey, but it did not affect handling time and predation rate. The shortest time to find the first prey and the highest number of predation occurred at 50 individuals of *N.lugens* provided (1.99 minutes for 28.2 individuals preyed) but with the lowest percentage of predation and weight gain (56.4% and 0.0004 g/ day respectively). The functional response of *Phidippus* sp was logarithmic, and the correlation between density and number of prey classified as weak to strong (r = 0.515).

Acknowledgment

Directorate General of Research and Development Strengthening, Ministry of Research, Technology and Higher Education of Indonesia with Basic Research Scheme 163/SP2H/LT/DRPM/2019 on behalf of the first author, contract number: T/29/UN.16.17/PT.01.03/PD-PP/2019.

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