# Lethal competition on joint predators during suppressing brown planthopper population

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**Abstract.** Joint predator is one technique to control brown planthopper (*Nilaparvata lugens*) in the rice field by combining two or more predator species having a positive interaction. This study aims to determine the effect of joint predator density (*Pardosa pseudoannulata* and *Phidippus* sp) on competition and its predatory rate in suppressing the *N.lugens* population. The study used a completely randomized design (CRD) by combining *P. pseudoannulata* or Pp (1,2,3 individuals) and *Phidippus* sp or Ps (1,2,3 individuals) to become Pp1Ps1, Pp1Ps2, Pp1Ps3, Pp2Ps1, Pp2Ps2, Pp2Ps3, Pp3Ps1, Pp3Ps2, Pp3Ps3. The parameters observed were predation rate, bodyweight, mortality of both predators, and competition model. The results showed that the composition difference between *P. pseudoannulata* and *Phidippus* sp affected on competition model and the predation. The predation rate of joint predators at different densities ranged from 40.4 – 47.0 individuals of *N.lugens* (80.8-94.0%) in one-day observation, and they consumed all prey until the third day's observation. The highest predation rate occurred for Pp3Ps3, but it was assumed it was not safe because of cannibalism and lethal competition. The Pp1Ps2 composition of joint predators was classified as safe, with 0 and 0.2 individuals' mortalities and followed by draw competition between two predators.

**Keywords**: Cannibalism, competition, interaction, intraguild predation, *Pardosa pseudoannulata, Phidippus* sp

## 1. Introduction

One of the primary pests that attack rice worldwide is brown planthopper or BPH (*Nilaparvata lugens* Stal 1854, Hemiptera: Delphacidae) [1, 2, 3]. It attacks rice plants by sucking its phloem sap, which usually contains nutrients and photosynthetic products. Rice plants become malnourished, grow stunted, the leaves turn yellow and wither -and finally- the plant dries up, called hopper burn. The impact of *N.lugens* attacks reported in Indonesia since the 1980s tends to increase yearly [4]. The highest attack occurred in 1998, covering an area of 120,000 ha [5], including in the endemic area [6]. Many scientists recommend controlling the *N.lugens* using natural enemies like the predator, and some of them can decrease *N.lugens* attacks significantly.

Spiders (Araneae) have been reported as predators of pest insects found in rice fields [7], including *Pardosa pseudoannulata* and *Phidippus* sp [8, 9, 10, 11, 12, 13, 14, 15, 16]. *P. pseudoannulata* is known as a generalist predator that catches the closest abundant prey [17, 18, 19] and consumes the prey without time

limitations [20]. Meanwhile, there is very little information on *Phidippus* sp as a predator of N.lugens, but the presence of Phidippus sp is also found in rice fields [14]. The effectiveness of single predation of *P. pseudoannulata* has been reported widely [21, 22, 23, 24, 25]. *P. pseudoannulata* can consume 5-24 *N.lugens* per day [22, 25, 26, 27, 28]. While *Phidippus* sp can consume 9-28 individuals of *N.lugens* per day, and it can prey up to a maximum of 96.0% of the prey provided for three days [29]. The predation of two predators increases when the prey increases [25, 29].

Each predator's ability is then generally used to predict the success rate in controlling *N.lugens*, assuming that increasing species and the number of predators will increase the suppression of pests in the field by sharing prey [30, 31, 32]. More than 62% of interactions among arthropods in the world are in the form of competition [33]. So, the potential for competition in the area is becoming very high between spider species [34, 35], affecting the consumption rate. There are three possibilities in interspecific competition: Killing and preying on competitors, killing but not preying on competitors, or killing but causing sublethal effects [35]. So, controlling pests using organisms with higher trophic levels can be successful if the natural enemies are complementary and suitable and there are no negative interactions [36].

It is necessary to select species compositions based on positive interaction to be used synergistically to enhance the efficacy of biological control [37]. The presence of joint predators such as *P. pseudoannulata* and *V. lineata* simultaneously causes a sublethal effect that harms both predators, but they can still suppress *N.lugens* populations more than 80% without intraguild [25]. The competition and cannibalism factors indicate a negative interaction that affected joint predators' predation rate. The safe and suitable composition of joint predators between *P. pseudoannulata* and *V. lineata* happens on the composition of 1:3 (1 individual of *P.pseudoannulata* and three individuals of *V.lineata*) [29]. This research was conducted to know joint predators' opportunities between *P.*
*pseudoannulata* and *Phidippus* sp to suppress *N.lugens* without followed by intraguild predation and find suitable composition in competitive conditions.

## 2. Material and Methods

### *2.1 Predator collection*

*P. pseudoannulata* and *Phidippus* sp. were gathered from rice fields in Pauh and Kuranji Districts, Padang, West Sumatera, and chosen according to the uniformity of body size. To avoid cannibalism, each predator was individually placed in a plastic cup and fed five N.lugens nymphs. Each time a predator consumed prey, the amount of prey was increased. All predators were starved for 24 hours after a week. This study uses 90 individuals of *P. pseudoannulata* and 90 individuals of *Phidippus sp* for all treatments and replications.

### *2.2 N. lugens* rearing

Since September 2019, *N. lugens* has been reared in the laboratory on the IR 42 rice variety. The seeds are soaked for 24 hours, then air-dried for one hour before being put into a culture jar (capacity = 25 liters) with 2 mm of water. The water level was kept at the level that allowed the seeds to be completely covered. Ten pairs of N. lugens adults were placed in a culture jar five to seven days after planting. The first nymph instar appeared seven to ten days later. A total of 2,250 of the second to third-instar nymphs were used in this study.

### *2.3 Treatment*

The study was conducted at the Laboratory of Insect Bioecology, Faculty of Agriculture, Universitas Andalas, in September-December 2019. The study used a Completely Randomized Design (RCD) with nine treatments and five replications. The treatment was the combination of the different compositions of two predators (*P. pseudoannulata* or Pp (1,2,3 individuals) and *Phidippus sp* or Ps (1,2,3 individuals), they were Pp1Ps1, Pp1Ps2, Pp1Ps3, Pp2Ps1, Pp2Ps2, Pp2Ps3, Pp3Ps1, Pp3Ps2, Pp3Ps3. The average daily minimum and maximum temperatures were 26.7°C and 29.2°C, respectively, with 70.6 percent and 80.9 percent relative humidity.

For each replication, two 360 mL plastic cups were provided. A heated nail with a diameter of approximately 2 mm was used to perforate the bottom of one cup. Three seven-day-old rice seedlings were inserted through a hole into the cup, with the roots positioned outside the cup. The second cup was filled to a height of 2 mm with water and placed on top of the first cup to serve as root development media. The nymphs of N. lugens were then placed in the cup in accordance with the treatment. Joint predators that had been starved for 24 hours were weighed using analytical scales with a precision of four decimals before being used in the treatment.

*2.4. Variables observed*

*2.4.1 Predation*

The number of N. lugens consumed by joint predators was calculated by counting the number of *N. lugens* consumed three times over a period of 24 hours. The percentage of predation was then calculated using the formula:

$$P = \frac{n}{N} \times 100 \qquad (1)$$

Where,

P = Predation
n = Number of *N.lugens* consumed
N = Number of *N.lugens* provided

*2.4.2 Joint predator mortality*

The two predators' mortality was counted for 3x24 hours and then calculated using the formula:

$$M = \frac{N_m}{N_p} \times 100 \qquad (2)$$

Where,

M = Mortality (%)
Nm = Number of predators dead
Np = Number of predators provided

*2.4.3 Bodyweight gain (g)*

Each predator's bodyweight was determined by weighing it with four-decimal precision using analytical scales. The difference between the bodyweight on the 1st to 3rd days compared to the bodyweight before treatment was used to calculate the bodyweight gain.

*2.4.4. Competition model*

The competition between two predators was monitored in a plastic cup within 1 × 24 hours, and a quantitative assessment was made according to Table 1.

**Table 1.** Criteria for determining a competition model in the laboratory between two predators (*Pardosa pseudoannulata* and *Phidippus* sp)

| Value | Criteria | Meaning |
|---|---|---|
| 0 | Lost | One predator is dead while all competitors are still alive, or the mortality percentage of one predator is higher than that of the competitor |
| 1 | Draw | All predators are alive, or all predators are dead |
| 2 | Win | There are deaths of both predators, but the mortality of one predator is less than that of the competitor |
| 3 | Very win | One predator is still alive, but the others are all dead |

*2.5 Data analysis*

Predation, predator mortality, and bodyweight growth data were analyzed using Statistix 8 software and the ANOVA and LSD tests at a 5% significance level. Graphics were used to display the competition.

## 3. Results and Discussion

*3.1 Predation rate*

During a one-day study, the predation rate of joint predators at various densities ranged from 40.4 to 47.0 individuals of N.lugens (80.8-94.0%). Pp3Ps3 had the highest predation rate, although it was considered that it was not safe due to cannibalism between *P. pseudoannulata* individuals or between Phidippus sp, and the predation was higher in Pp1Ps1, Pp1Ps2, and Pp2Ps1 compositions, but not in other compositions. When the number of *P. pseudoannulata* or Phidippus sp stayed constant at one individual, joint predator predation on N.lugens increased (Table 2). Until the third day of observation, all prey was consumed by combined predators in all compositions (Figure 1).

**Table 2.** The predation rate of joint predators (*Pardosa pseudoannualata* and *Phidippus* sp) on *Nilaparvata lugens* under competitive conditions (one-day observation)

| Joint predator composition | Predation rate | | |
|---|---|---|---|
| | Individuals | | Percentage (%) |
| Pp1Ps1 | 40.4 | d | 80.8 |
| Pp1Ps2 | 42.0 | bcd | 84.0 |
| Pp1Ps3 | 45.4 | ab | 90.8 |
| Pp2Ps1 | 41.2 | cd | 82.4 |
| Pp2Ps2 | 46.8 | a | 93.6 |
| Pp2Ps3 | 45.2 | abc | 90.4 |
| Pp3Ps1 | 46.0 | ab | 92.0 |
| Pp3Ps2 | 44.2 | abcd | 88.4 |
| Pp3Ps3 | 47.0 | a | 94.0 |

Notes: Pp = *Pardosa pseudoannulata*, Ps = *Phidipppu*s sp, 1,2,3 = population number.
The number followed by different small letters are significantly different according to the LSD test at a 5% significance level

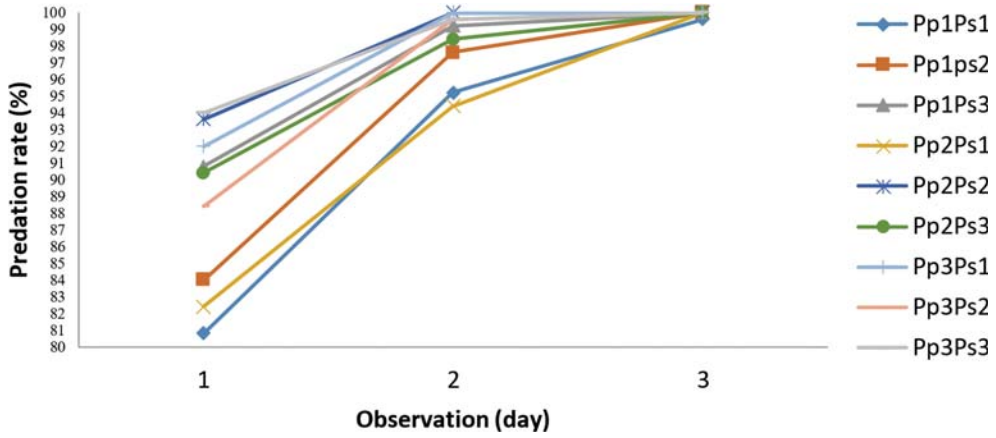


**Figure 1.** Accumulated predation percentages of joint predators (*Pardosa pseudoannulata* and *Phidippus* sp) on *Nilaparvata lugens* under competitive conditions during three days of observation.

*3.2 Joint predator mortality*

Unfortunately, deploying joint predators at varying densities to lower the *N.lugens* population resulted in severe and even lethal competition. *P.pseudoannulata* killed other *P.pseudoannulata* as well as *Phidippus* sp., while *Phidippus* sp. did not kill *P.pseudoannulata* or other *Phidippus* sp. Although not considerably different, the deaths of *P. pseudoannulata* and *Phidippus* sp varied among treatments. With mortalities of 0 and 0.2 individuals of the two predators, the Pp1Ps2 composition of joint predators was classified as safe (Table 3).

**Table 3.** The mortality of joint predators (*Pardosa pseudoannulata* and *Phidippus* sp) on *Nilaparvata lugens* under competitive conditions (one-day observation).

| Joint predator composition | Mortality | | | | | |
|---|---|---|---|---|---|---|
| | *P.pseudoannulata* | | | *Phidippus* sp | | |
| | Individuals | % | | Individuals | % | |
| Pp1Ps1 | 0.4 | 40.0 | A | 0.2 | 20.0 | a |
| Pp1Ps2 | 0 | 0 | A | 0.2 | 10.0 | a |
| Pp1Ps3 | 0.4 | 40.0 | A | 0.8 | 26.7 | a |
| Pp2Ps1 | 0.4 | 20.0 | A | 0.2 | 20.0 | a |
| Pp2Ps2 | 0.8 | 40.0 | A | 0.4 | 20.0 | a |
| Pp2Ps3 | 1.0 | 40.0 | A | 0.8 | 26.7 | a |
| Pp3Ps1 | 1.4 | 47.0 | A | 0.2 | 20.0 | a |
| Pp3Ps2 | 1.2 | 40.0 | A | 0.6 | 30.0 | a |
| Pp3Ps3 | 1.8 | 60.0 | A | 1.2 | 40.0 | a |

Notes: Pp = *Pardosa pseudoannulata*, Ps = *Phidipppu*s sp, 1,2,3 = population number
The numbers followed by different small letters are significantly different according to the LSD test at a 5% significance level

Cannibalism and competition increased the mortality of joint predators during three days of observation, with the highest impact found for *P. pseudoannulata*. *P. pseudoannulata* mortality was higher than *Phidippus* sp, which reached 87 %, while *Phidippus* sp mortality reached 60% on the third day of observation.

During a three-day observation period, cannibalism and competition enhanced the mortality of joint predators, with *P. pseudoannulata* having the most impact. On the third day of observation, P. *pseudoannulata* mortality was higher than *Phidippus* sp, reaching 87 %, while *Phidippus* sp mortality was 60 %.

There was no death on *P. pseudoannulata* in Pp1Ps2, and the lowest death on *Phidippus* sp occurred in Pp1Ps2 also, and the highest mortality of both predators occurred in the highest composition, that was, in Pp3Ps3. In this condition, cannibalism and competition occurred between individuals of *P. pseudoannulata*, followed by the predation of *P. pseudoannulata* on *Phidippus* sp, and weak competition occurred between individuals of *Phidippus* sp (Figure 2).

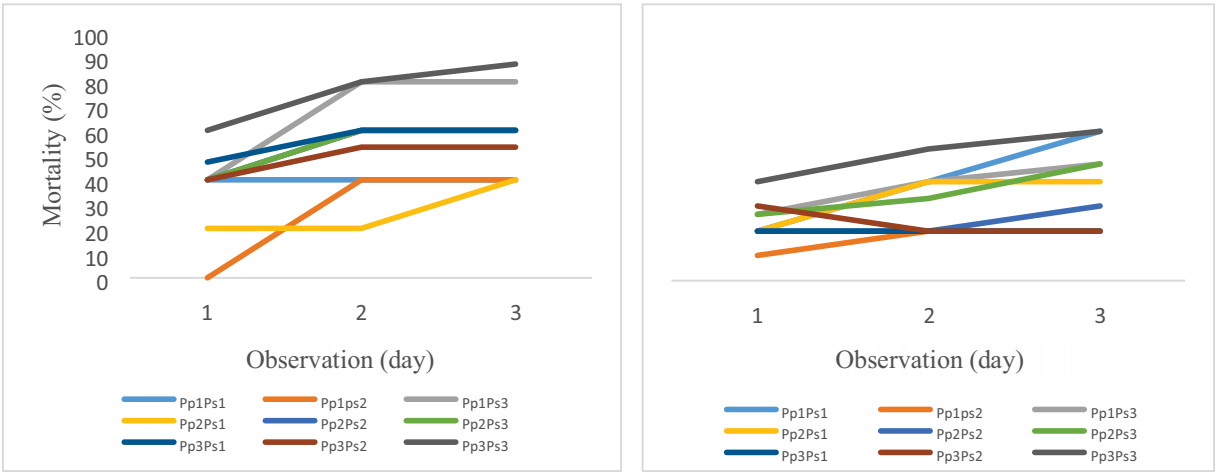


**Figure 2.** Joint predator mortality in suppressing *Nilaparvata lugens* under competitive conditions (left, *Pardosa pseudoannulata* mortality; right, *Phidippus* sp mortality) during three days of observation.

*3.3 Bodyweight gain (g)*

The bodyweight gain of *P.pseudoannulata* at different densities ranged from -0.0149 to 0.0185 g and ranged from -0.0169 to 0.0145 g for *Phidippu*s sp in one-day observation. The data revealed a decrease or an increase in both predators' bodyweight despite preying on BPH. The highest bodyweight gain of *P.pseudoannulata* was found on Pp3Ps1, and the highest bodyweight gain of *Phidippus* sp was found on PP3Ps2, but it was no different from other compositions (Table 4).

*3.4 Competition model*

The survival ability of *Phidippus* sp was higher than *P. Pseudoannulata,* which obtained a winning scenario in almost all treatments. During three days of observation, the draw competition happened on Pp1Ps1 or Pp1Ps2. This was because *P.pseudoannulata* have been had cannibalistic behavior and killed the competitors but *Phidippus* sp did not. Ketika kepadatan salah satu atau keduanya ditambah. Competition became fluctuating when the composition of the two predators increased (Figure 3).

**Table 4.** The bodyweight of joint predators (*Pardosa pseudoannulata* and *Phidippus* sp) on *Nilaparvata lugens* under competitive conditions (one-day observation).

| Joint predation composition | Bodyweight gain (g) | | | |
|---|---|---|---|---|
| | *Pardosa pseudoannulata* | | *Phidippus* sp | |
| Pp1Ps1 | -0.0149 | A | -0.0011 | a |
| Pp1Ps2 | 0.0059 | A | 0.0001 | a |
| Pp1Ps3 | -0.0030 | A | 0.0106 | a |
| Pp2Ps1 | 0.0046 | A | -0.0169 | a |
| Pp2Ps2 | 0.0032 | A | -0.0095 | a |
| Pp2Ps3 | 0.0097 | A | 0.0060 | a |
| Pp3Ps1 | 0.0185 | A | 0.0010 | a |
| Pp3Ps2 | 0.0111 | A | 0.0145 | a |
| Pp3Ps3 | 0.0018 | A | 0.0110 | a |

Notes: Pp = *Pardosa pseudoannulata*, Ps = *Phidipppu*s sp, 1,2,3 = population number
The numbers followed by different small letters are significantly different according to the LSD test at a 5% significance level

*Pardosa pseudoannulata* and *Phidippus* sp are two species of generalist predators from Araneae or spiders, and both are found together in rice fields [1, 9, 14, 15, 38]. The different densities of joint predators, competition, and cannibalism affected the predation rate of joint predators. This research revealed that there was a lethal interaction between the two predators in the form of killing and prey the competitor, especially for *P.pseudoannulata,* and that interaction was classified as level 1 competition according to Lucas [35] so that they only have a little potency to be joint predators due to their behavior in finding prey and facing competitor.

The competition can increase or suppress the predation rate or interrupt the existence of competitors [19, 25, 29]. Their existence will increase predation if they cooperate with each other or give opportunities to get prey without showing negative interaction. On the contrary, their existence will reduce predation if they suppress each other [25]. Otherwise, it can trigger an increase in the population of herbivores due to reduced pressure from natural enemies that prey on one another [39]. Very strong competition can reduce the predation rate, whereas weak competition can increase the predation rate and pressure on prey [40, 41].

Cannibalism generally is affected by the availability of food, starvation, densities, size, and foraging behavior [42, 43, 44, 45]. Many reasons were found related to cannibalism. It occurs when large or heavy spiders cannibalize smaller or lighter spiders [45] due to the fear of retaliation [46], when females cannibalize males to increase the number of offspring [47], or when females cannibalize young females [48]. Cannibalism can occur when food is rare [49], food is abundant [50], or there is poor-quality prey [51].

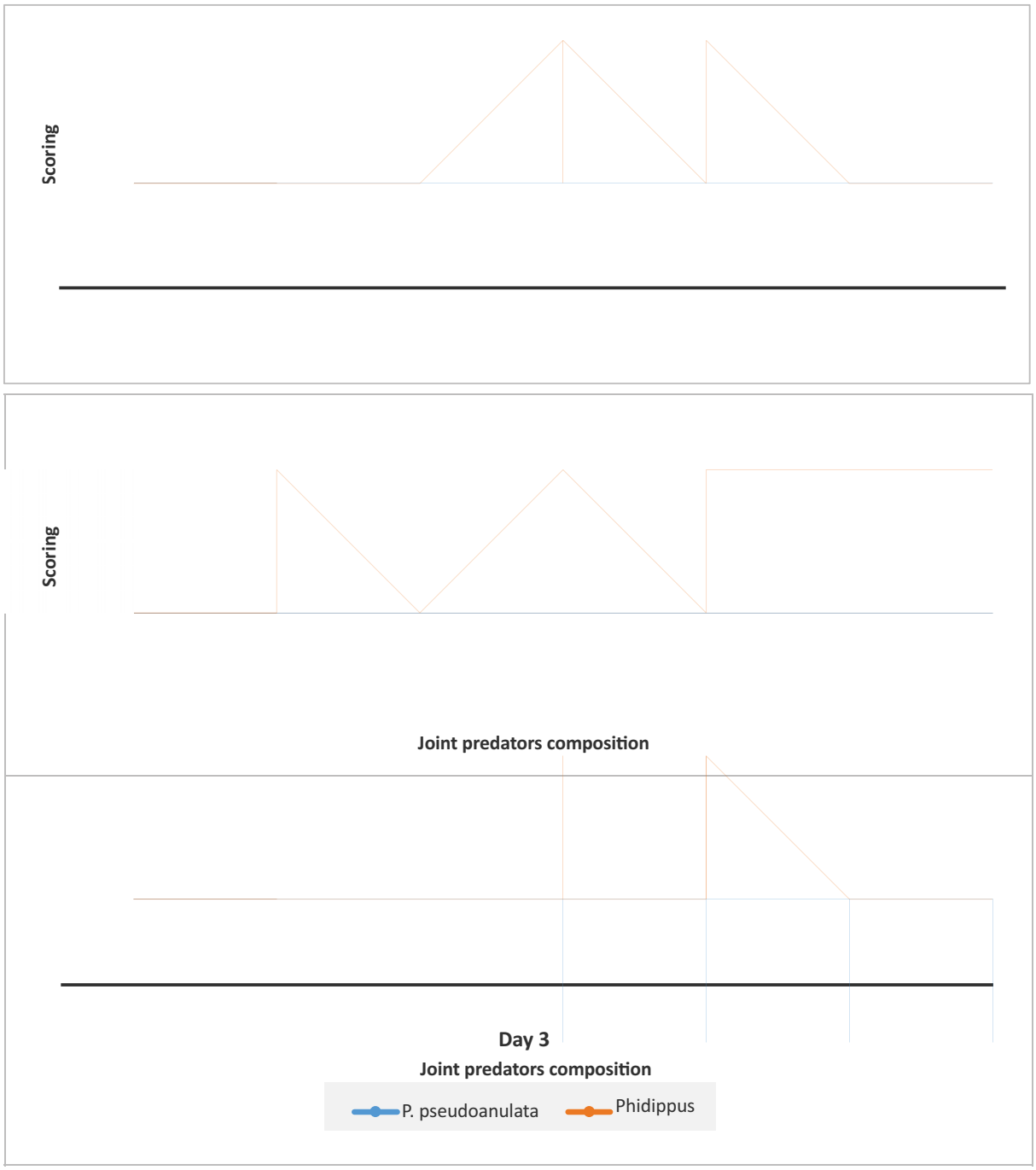


**Figure 3.** Competition model of joint predators (*Pardosa pseudoannulata* and *Phidippus* sp) to suppress *Nilaparvata lugens* population at different densities (3 days observation)

## 4. Conclusions

The composition difference between *P. pseudoannulata* and *Phidippus* sp affected on competition model and the predation. The predation rate of joint predators at different densities ranged from 40.4 – 47.0

individuals of *N.lugens* (80.8-94.0%) in one-day observation, and they consumed all prey until the third day's observation. The highest predation rate occurred for Pp3Ps3, but it was assumed that it was not safe because of cannibalism and lethal competition. The Pp1Ps2 composition of joint predators was classified as safe, with mortalities of 0 and 0.2 individuals and followed by draw competition of the two predators.

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