CONTROLLING BROWN PLANTHOPPER *(Nilaparvata lugens* Stal*)* BY JOINT PREDATORS *(Pardosa pseudoannulata* Boesenberg and Strand and *Verania lineata* Thunberg) UNDER COMPETITIVE CONDITIONS

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Abstract — *Pardosa pseudoannulata* and *Verania lineata* are two generalist predators commonly found in rice fields. Only a few references indicate their presence as joint predators resulting in positive interactions to brown planthopper without competition. The research aimed to determine the predation rate of joint predators in competitive conditions. The research was conducted in the laboratory using a Completely Randomized Design (CRD) with different combinations of joint predators. The density of *P. pseudoannulata* (P) and *V. lineata* (V) were 1, 3, 5 individuals per treatment (P1V1, P1V3, P1V5, P3V1, P3V3, P3V5, P5V1, P5V3, and P5V5). Each treatment had five replications. The results showed that competition and cannibalism factors indicate a negative interaction that affected the predation rate of joint predators. The ability of *P. pseudoannulata* to survive in competitive conditions was lower than *V. lineata*. The suitable and safe combination was using one (1) *P. pseudoannulata* and three (3) *V. lineata* (P1V3) with 89.6% predatory rate on *Nilaparvata lugens* Stål on the first day, and with the lowest death rate of two predators. The P1V3 combination also had an increase in bodyweight of *P. pseudoannulata* and a competition model that resulted in draw conditions. Therefore, before using some predators to control the BPH optimally, there is a need to minimize the impact of competition and cannibalism on them.

Keywords — **Brown planthopper, rice, lady beetle, wolf spider, prey consumption, cannibalism, competition.**

INTRODUCTION

Brown planthopper or BPH (*Nilaparvata lugens* Stål, Hemiptera: Delphacidae), is the primary pest of rice worldwide. Its attack causes losses and crop failures in many countries. The first attack of BPH in Indonesia that causes "hopperburn" occurred in 1980s, and there is an increase of attacks every year (Baehaki and Mejaya, 2014). In West Sumatra, one of provinces in Indonesia, the attack increases rapidly during 2015-2017, followed by attacks of grassy rice stunt and ragged stunt viruses (Food Crops and Horticultural Protection Agency of West Sumatera, 2019). Controlling BPH using natural enemies such as predator has not been the best choice for farmers because the results are not measurable, and the method does not guarantee population suppression of BPH, as is the case with synthetic pesticides.

The effectiveness of single predators, such as *Pardosa (syn= Lycosa pseudoannulata* (Araneae: Lycosidae) and *Verania* (syn= *Micraspis*) *lineata* (Coleoptera: Coccinellidae) has been reported widely (IRRI, 1982; Heong et al., 1990; Preap et al., 2001; Laba, 2001; Syahrawati et al., 2015). P. *pseudoannulata* is a generalist predator that does not have specific preferences for prey and tends to catch the closest abundant prey (Reissig et al., 1985; Riechert and Lawrence, 1997; Foelix, 2011). Furthermore, *P. pseudoannulata* is polyphagous predator, very generalist, and time generalist, i.e., this species consumes the prey without time limitations (Suana and Haryanto, 2013). On the contrary, *V. lineata* is a generalist predator, but it has specific prey preferences (Karindah, 2011). Yasuda and Kimura (2001) and Snyder et al. (2004) reported that spiders and lady beetles are top predators and intraguild predators.

Based on some experiments on single predation in the laboratory, P. *pseudoannulata* can consume 5-15 BPH per day (Shepard et al., 1987; Heong et al., 1990; Lubis, 2005; Syahrawati et al., 2015), while *V. lineata* can consume 1-11 BPH per day (Lubis, 2005; Karindah, 2011; Syahrawati et al., 2015). The data generally used to predict the success rate in controlling BPH, assuming that increasing species and number of predators will increase the suppression on pests in the field by sharing prey (Morin, 1999; Riechert, 1999; Sembel, 2010). Only a few studies have shown that joint predators can significantly suppress the BPH population. Therefore, research on this topic needs to be done.

Letourneau et al. (2009) stated that controlling pests using organisms with higher trophic levels can be beneficial if the natural enemy species are complementary, suitable, and there are no negative interactions. However, with of *P. pseudoannulata* as well and as *V. lineata* are generalist predators, the potential for competition in the field is very high (Snyder and Ives, 2001; Lucas, 2005), which could influence their predatory behavior and the consumption rate. Syahrawati et al. (2015) reported that the presence of joint predators like the *V. lineata* and *P. pseudoannulata* simultaneously causes a sublethal effect that harms both predators, but they can still suppress BPH populations more than 80% without intraguild predation (IGP). Lucas (2005) described three possibilities that occur in interspecific competition: Killing and preying on competitors, killing but not preying on competitors, or killing but causing sublethal effects.

Preap et al. (2001) reported that joint predation by *P. pseudoannulata* predation and Araneus inustus increase the pressure on the BPH population. The predation rate of *P. pseudoannulata* is higher than

A. inustus two times. The optimum ratio between predators and BPH is 1:11 to 1:20. Furthermore, the effective and suitable composition of joint predators between *P. pseudoannulata* and *V. lineata* is not yet known. Varshney and Ballal (2019) stated that it is needed to select species compositions based on positive interaction so that they can be used synergistically to enhance the efficacy of biological control. This research was conducted to determine joint predators' ability to suppress BPH and to find the suitable composition of them in competitive conditions.

MATERIALS AND METHODS

Predator Collection

P. pseudoannulata and V. lineata (Figure 1) were collected using small bottles directly from rice fields in Pauh District, Padang, West Sumatera in June 2019. The predators were transferred into a plastic cup separately to avoid cannibalism and fed three to five nymphs of *N. lugens* at the Laboratory of Insect Bioecology, Faculty of Agriculture, Universitas Andalas. Each time the prey was already consumed, an additional prey was added . The predators were starved for 24 hours before use after one week. There were 135 individuals of *P. pseudoannulata* and 135 individuals of *V. lineata* of a similar size provided for all treatments and replications.

Fig.1. The two predators used in the study; Left. *Pardosa pseudoannulata* (body length = 7.1 mm), Right. Verania lineata (body length = 4.7 cm).

N. lugens Rearing

N. lugens was reared in the laboratory at the beginning of October 2017 on IR 42 variety. The seeds were 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, covering the whole seeds. Five to seven days after sowing, ten pairs of *N. lugens* adults were placed into a culture jar. Seven to ten days later, the first nymph instar emerged. It was needed 50 individuals for each treatment. The total number of nymphs (2nd to 3rd instars) needed in this study was 2, 250 individuals (Figure 2).

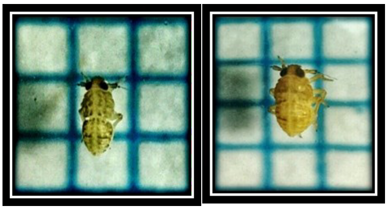

Fig.2. The nymphs of *Nilaparvata lugens* used in the study; Left. 2nd instar (body length = 1.2 mm), Right, 3rd instar (1.8 mm).

Treatments

The study was conducted at the Laboratory of Insect Bioecology, Faculty of Agriculture, Universitas Andalas, from June-August 2019. The average minimum and maximum daily temperatures were 26.7°C and 29.2°C, respectively, while the average minimum and maximum daily relative humidity were 70.6% and 80.9%, respectively. The study used a Completely Randomized Design (CRD) with treatments in the form of different compositions of the two predators (P = *P. pseudoannulata, V= V. lineata*), such as 1, 3, and 5 individuals of each predator (P1V1, P1V3, P1V5, P3V1, P3V3, P3V5, P5V1, P5V3, P5V5). Each treatment was done in five replications.

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 approximately 2 mm. Three rice seedlings aged seven days were placed into the cup through a hole, while the roots were positioned outside the cup. The second cup was filled with water with a height of 2 mm and placed overlapping with the first cup to be used as root growth media. Then, the nymphs of *N. lugens* were placed into the cup according to the treatment. Joint predators that had been starved for 1 X 24 hours and weighed before use in the treatment using analytical scales with a precision of 4 decimals.

Data Gathered

Predation. The number of *N. lugens* consumed by joint predators was determined by counting the number of *N. lugens* consumed for 3x24 hours. Then, the percentage of predation was computed using the following formula:

$$P = \frac{n}{N} \times 100$$

where, P is Predation, n is Number of *N. lugens* consumed, and N is Number of *N. lugens* provided.

Joint Predator Mortality. The mortality of the two predators was counted for 3x24 hours and then measured using the following formula:

$$M = \frac{nm}{Np} x\ 100$$

where M is Mortality (%), nm is the Number of predators dead, and Np is the Number of predators provided.

Bodyweight (g). The body weight of each predator was measured by weighing it using analytical scales with a precision of four decimals. The bodyweight gain was obtained by measuring the difference in the bodyweight in the 1st to 3rd day compared to the bodyweight before treatment.

Competition Model. Competition between two predators was observed in a plastic cup within 1 x 24 hours, and then a quantitative assessment was given according to Table 1.

Table 1. The criteria to determine competition model between two predators *(Pardosa pseudoannulata* and *Verania lineata)* in the laboratory.

Value	Criteria	Meaning
0	Lost	One predator is dead, while all competitors are still alive or the mortality percentage of one predator are 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.

Data Analysis

The data about predation rate and predator mortality were statistically analyzed with analysis of variance (ANOVA), and the significant difference was tested under CRD design at probability level 0.05% by using statistic 8 software. The data are displayed in a table with the standard error. Furthermore, the bodyweight gain data and competition model are displayed in the form of graphics.

RESULTS AND DISCUSSION

Predation Rate (Individuals)

The predation rate of joint predators at different densities ranged from 43.2-49.4 individuals of BPH (86.4-98.8 %) in one-day observation. The highest predation rate occurred for P5V5, but it was assumed that it was not safe because of the cannibalism between the predator *P. pseudoannulata*, which did not occur for *V. lineata*, having the predation rate not much higher than other combinations. The predation of joint predators on BPH increased with the constant number of one individual of *P. pseudoannulata* , but the number of *V.lineata* increased. Increasing the *P.pseudoannulata* to three individuals resulted to a decrease in the predation rate, even as the number of *V.lineata* increased, and fluctuating when the number of *P.pseudoannulata* was increased to five individuals (Table 2).

In the P1V1, P3V1, and P1V3 combinations, joint predators tended to consume all prey until the third-day observation, but predators in the other combinations consumed their prey on the second day (Figure 3).

Bodyweight Gain of Joint Predators (g)

The bodyweight gain of predators after the third observation day was higher in *P. pseudoannulata* than *V. lineata.* The bodyweight of *P.pseudoannulata* fluctuated, except for P1V3, P1V5, and P3V3 combinations, and the increase in bodyweight of *P. pseudoannulata* in P3V3 was higher than *P.pseudoannulata* in P1V3 and P1V5. Meanwhile, the bodyweight of *V.lineata* decreased, except for P3V3 and P5V3 combinations, but the increase in bodyweight of *V. lineata* in P3V3 was higher than *V. lineata* in P5V3. The P1V3 combination was classified as a suitable and safe for joint predators because the bodyweight gain was only reached by consuming BPH, not from cannibalism or intraguild predation (Figure 4).

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

Joint Predator Group	Predation (Individuals) ± SE	Predation (%) ± SE
P1V1	43.2 ± 2.7	86.4 ± 4.9
P1V3	44.8 ± 2.9	89.6 ± 5.9
P1V5	45.8 ± 1.9	91.6 ± 3.8
P3V1	47.2 ± 1.3	94.4 ± 2.7
P3V3	45.6 ± 1.8	91.2 ± 3.6
P3V5	45.2 ± 0.6	90.4 ± 1.2
P5V1	48.0 ± 0.8	96.5 ± 1.7
P5V3	47.6 ± 1.1	95.2 ± 2.1
P5V5	49.4 ± 0.4	98.8 ± 0.8

Note: SE = standard error

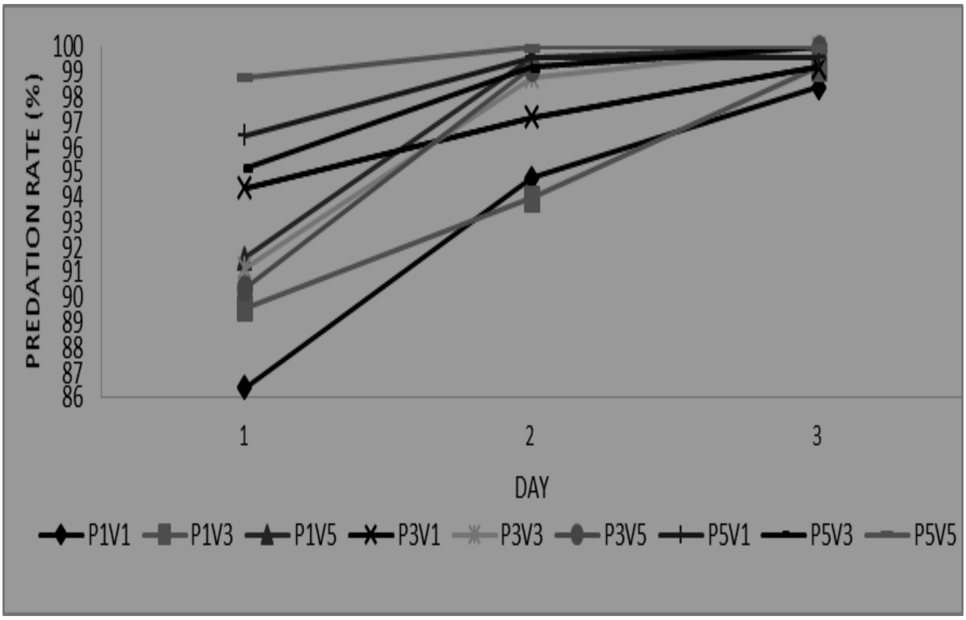

Fig. 3. Accumulated predation percentages of joint predators (*Pardosa pseudoannulata* and *Verania lineata*) on *Nilaparvata lugens* under competitive conditions during three days.

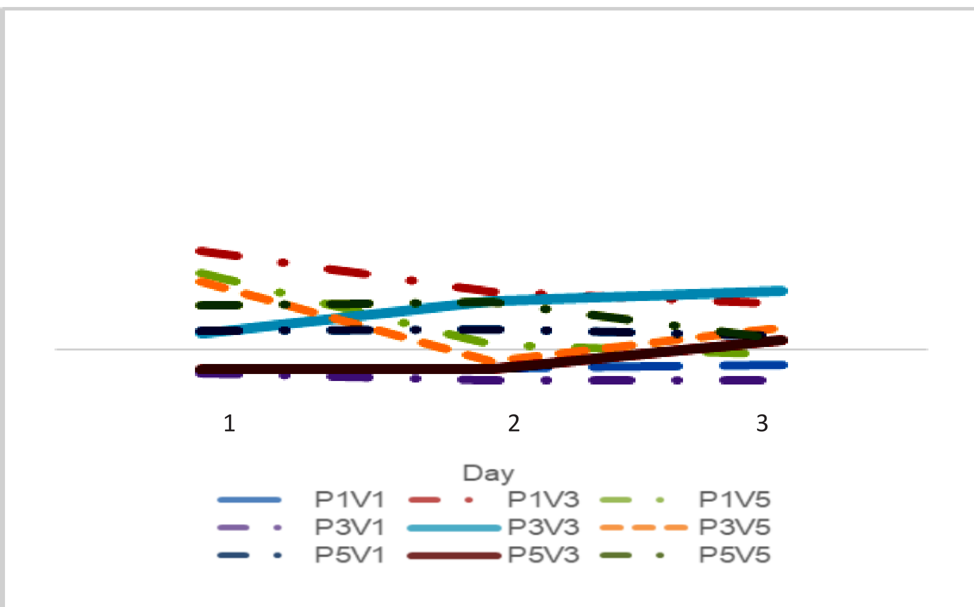

Fig. 4. The development of joint predator weight (g). (Left: *Pardosa pseudoannulata*, Right: *Verania lineata* after consuming *Nilaparvata lugens* during three days observation.

Joint Predator Mortality

Unfortunately, the attempt to suppress the BPH population by using joint predators at different densities resulted in harmful and even lethal competition (competitors killed but did not prey on each other). The deaths of both *P. pseudoannulata* and *V. lineata* fluctuated among treatments. The P1V3 composition of joint predators was classified as safe, with mortalities of 0 and 0.2 individuals of the two predators (Table 3).

Cannibalism and competition increased the mortality of joint predators during three days observation, with the highest impact found for *P. pseudoannulata* having High mortality than *V. lineata*. Increase in mortality to 73.33% of *P. pseudoannulata* while *V. lineata* mortality reached 46.67% on the third-day observation. There was no death on *P. pseudoannulata* in P1V1, and there was no death on *V. lineata* in P5V1, but the highest mortality of both predators occurred in the highest combination, that is, in P5V5. In this condition, cannibalism and competition occurred between individuals of *P. pseudoannulata,* whereas and weak competition occurred between *V. lineata* individuals (Figure 5).

Competition Model

The survival ability of *P. pseudoannulata* was lower than *V. lineata,* with a high mortality rate. *V. lineata* obtained a winning scenario in almost all treatments. As observed during the three-day observation period, *P. pseudoannulata* won the competition when the density remained at one individual, while *V. lineata* continued to increase. When the density of both predators was added, *V. lineata* won the competition. The draw competition was seen in the density of P1V1 and P1V3 combinations. This was because unlike *P. pseudoannulata,* the predator *V. lineata* did not exhibit cannibalistic behavior. The presence of *P. pseudoannulata* did not serve as threat to *V. lineata* unless the former made a netting to move to another site, not to trap the prey or the competitor.

Table 3. Mortality of joint predators (*Pardosa pseudoannulata* and Verania *lineata*) on *Nilaparvata lugens* under competitive conditions (one-day observation).

Joint Predator Group	*P. pseudoannulata* Mortality (Individuals) ± SE	*V. lineata* Mortality (Individuals) ± SE
P1V1	0.2 ± 0.2	0.2 ± 0.2
P1V3	0 ± 0	0.2 ± 0.2
P1V5	0 ± 0	0.4 ± 0.2
P3V1	1.0 ± 0.4	0.6 ± 0.2
P3V3	0.6 ± 0.3	0.2 ± 0.2
P3V5	1.2 ± 0.5	0.4 ± 0.2
P5V1	1.8 ± 0.8	0.2 ± 0.2
P5V3	1.2 ± 0.5	0.2 ± 0.2
P5V5	1.8 ± 0.4	1.0 ± 0.3

Note: SE = standard error

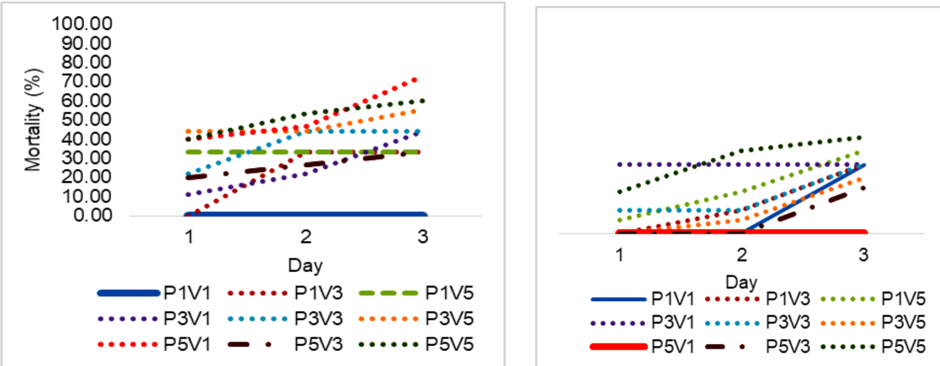

Fig. 5. Joint predator mortality in suppressing *Nilaparvata lugens* under competitive conditions (Left: *Pardosa pseudoannulata* mortality; Right: V*erania lineata* mortality) during three days observation.

The netting often trapped *V. lineata* in flight. However, when *V. lineata* was trapped, *P. pseudoannulata* did not try to prey on it (Figure 6). Both *P. pseudoannulata* and *V. lineata* are two species of generalist predators from different taxonomic classes, and both are often found together in rice fields (Syahrawati et al., 2014). Previous research revealed that there is a sublethal interaction between the two predators, but they have a potency to be joint predators due to their behavior in finding prey (Syahrawati et al., 2015). From this research, a novel information was obtained that competition and cannibalism indicate a negative interaction between the two predators which in turn affected the predation rate although the differences were not significant.

The predation rate of joint predators increased with only one individual of *P. pseudoannulata*, even though the *V. lineata* increased in number. Cannibalism did not occur between individuals in *V. lineata* but only occurred between individuals of *P. pseudoannulata*, while competition occurred between inter- and intra-predators. The P1V3 combination was classified as suitable and safe because the two predators in this treatment were able to consume 89.6% of BPH on the first day and tended to consume all prey until the third days observation. The P1V3 combination also had an increase in the bodyweight of *P. pseudoannulata*, the lowest joint predator mortality, and a competition model that resulted in the draw condition. Approximately 62% of interactions among arthropods in the world are in the form of competition (Kaplan and Denno, 2007). Competition for nutrition does not only occur between predator and predator but also between predator and parasitoid as reported by Hussaini and Askar (2019) and Varshney and Ballal (2019). The competition can decrease or increase the predation rate or disturb the existence of competitors (Foelix, 2011; Syahrawati et al., 2015).

On the other hand, it can trigger an increase in the herbivore populations due to reduced pressure from natural enemies that prey on one

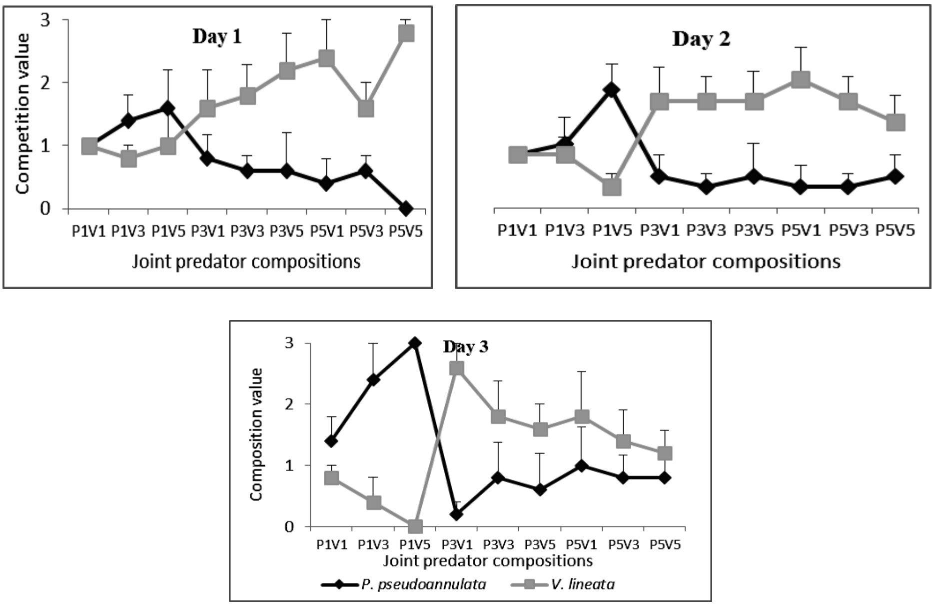

Fig. 6. Competition model of joint predators (*Pardosa pseudoannulata* and *Verania lineata*) to suppress *Nilaparvata lugens* population at different densities (3 days observation).

another (Denno et al., 2002). Very strong competition can reduce the predation rate, whereas a weak competition can increase the predation rate and pressure on prey (Menge and Sutherland, 1976; MacArthur, 1984).

Furthermore, the cannibalism incidence is affected by the availability of food, starvation, densities, size, and foraging behavior (Wagner and Wise, 1997; Samu et al., 1999; Rickers and Scheu, 2005; Gonzalez, 2012). Cannibalism generally occurs when large or heavy spiders cannibalize smaller or lighter spiders (Gonzalez, 2012), due to the fear of retaliation (Hvam et al., 2005), when females cannibalize males to increase the amount of offspring (Wu et al., 2013) or when females cannibalize young females (Torres-Contreras et al., 2015). Cannibalism can occur when food is rare (Polis, 1981), food is abundant (Wagner et al., 1999), or there is poor-quality prey (Snyder et al., 2000). Then, cannibalism also occurs among Coccinellidae, especially on eggs and larvae (Khan et al., 2003; Burgio et al., 2005; Pervez et al., 2006; Bayoumy and Michaud, 2015a; Bayoumy and Michaud, 2015b), but not between adults (Syahrawati et al., 2015).

CONCLUSIONS

This study demonstrated that competition and cannibalism factors indicate a negative interaction that affected joint predators' predation rate. The ability of *P. pseudoannulata* to survive in a competitive condition was lower than *V. lineata*.

The P1V3 composition (one *P. pseudoannulata* and three *V. lineata)* was suitable and safe because the predators preyed on the BPH up to 89.6% on the first day and reached the lowest mortality of both predators.

The P1V3 (five *P. pseudoannulata* and five *V. lineata*) composition also increased the *P. pseudoannulata* bodyweight and a competition model that resulted in the draw condition. Therefore, before using some predators to control the BPH optimally, there is a need to ensure the impact of competition and cannibalism.

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