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Short Communication: *Silba adipata* (Diptera: Lonchaeidae) parasitoids on cayenne pepper (*Capsicum frutescens*) in Bali, Indonesia

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Abstract. *Yuliadhi KA, Supartha IW, Darmiati NN, Bangun A, Yudha IKW, Utama IWEK, Wiradana PA. 2021.* Silba adipata *(Diptera: Lonchaeidae) parasitoids on cayenne pepper (*Capsicum frutescens*) in Bali, Indonesia. Biodiversitas 22: 3929-3935.* The black fig fly *(Silba adipata)* is newly emerging pests that attack cayenne pepper (*Capsicum frutescens* L.) plants in Bali Province, Indonesia. This study aimed to determine the parasitoid type, community structure, distribution, and parasitization rate of the parasitoids of *S. adipata* on cayenne pepper in Bali. The sampling method employed in this study involves purposive sampling techniques on 100-150 pieces of cayenne pepper infested with *S. adipata* at each location point, with the emerging parasitoids identified morphologically. Three types of parasitoid species were associated with *S. adipata,* which include *Asobara japonica* Belokobylskij, *Fopius arisanus* (Sonan), *and Diachasmimorpha longicaudata* (Ashmead). The parasitoid community structure associated with *S. adipata* had a low abundance index, low diversity index, and a moderate dominance index. Based on the distribution of the three parasitoids, *D. longicaudata* is distributed evenly in Bali, whereas *F. arisanus* was not found in Jembrana . Conversely, *A. japonica* was only found in Badung, Bangli, Gianyar, and Klungkung. As summary, *D. laungicaudata* had the highest parasitization rate compared to the *F. arisanus* and *A. japonica. D. longicaudata* is a potential parasitoid, which can be studied for the future biological control of *S. adipata.*

Keywords: Biological control, Black Fig Fly, Braconidae, geographical distribution, *Silba adipata*

INTRODUCTION

Cayenne pepper (*Capsicum frutescens* L.) is a horticultural commodity that is widely cultivated in Indonesia, which corresponds to an increase in national cayenne pepper production increased from 800,484 tons in 2014 to 1,335,608 tons in 2018 (Indriani et al. 2020). However, the production of white cayenne pepper in Bali Province, Indonesia has fluctuated since it increased from 28,440 tons in 2014 to 38,358 tons in 2016 and then decreased to 31,655 tons in 2018 (BPS 2019).

The decreasing cayenne pepper production can be caused by abiotic and biotic factors (Borowski et al. 2019). Also, the cayenne pepper plantation in Bogor (West Java) has been infested by a new pest-black fig fly (BFF) *Silba capsicarum* (Diptera: Lonchaeidae) (MacGowan and Rauf 2019). According to previous study, 911 adults of *S. capsicarum* were recovered from 281 chilli peppers (MacGowan and Rauf 2019). *Silba adipata* McAlpine is a new pest that infests cayenne pepper in Bali, and its morphology differs from that of the *S. capsicarum* species previously reported in Bogor, West Java. More so, one of the morphological differences is a puncture symptom from the ovipositor a brown dot on the immature fruit surface (Merta 2019).

Due to the lack of bioecological information on pest management, farmers use broad-spectrum. However, this tactic provides a negative impact on the environment and the health of consumers and farmers themselves (Lee et al. 2013). Alternative strategy such as parasitoids is promising in suppressing pest infestations peaks (Bezerra et al. 2021). Naturally, interspecific competition between parasitoids may occur if two or more species attack the same host species in order to compete for resources (Harvey et al. 2013), or may have an additive effect. This competition may also allow for the emergence of fundamental potential in biological pest control strategies, such as the displacement of one parasitoid species by another or a reduction in overall effectiveness for the target pest (Wang et al. 2016). This competition is also known as "intra and interspecific competition" (Harvey et al. 2013). As a result, understanding parasitoid types and levels of parasitization is critical in biological control programs against specific pest (Mi et al. 2021). This study investigated the species, community structure, distribution, and parasitization rate of parasitoids against the black fig fly, *S. adipata* on cayenne pepper in Bali Province, Indonesia.

MATERIALS AND METHODS

Study location

The study was conducted from February to April 2020 in 8 districts and 1 city in Bali Province, Indonesia as shown in Figure 1. Laboratory research was conducted at the Integrated Pest and Disease Management Laboratory (IPMLab) at the Faculty of Agriculture, Udayana University, Bali.

Sampling method

The sampling location in each district and city was determined based on the cayenne pepper data provided on the Bali Province BPS website (bali.bps.go.id). 100-150 cayenne pepper samples infested by *S. adipata* were taken purposively from each location point, and then stored in sterile plastic bags, labeled, and brought to the laboratory for observation.

Maintenance procedure

The white cayenne pepper was maintained by placing it in a transparent plastic container with a 6 cm lower diameter, 9 cm upper diameter, and 12.5 cm height. The container was filled with 20 g of sandy soil, which was used as a medium for pupation. The humidity level was maintained by spraying with water, and infected cayenne pepper was placed in the container and covered with gauze. Each container was covered with gauze, labeled with the field data, and placed in rearing containers until emergence of flies or parasitoids.

Parasitoid identification

The identification of parasitoid type was carried out by analyzing the morphological characteristics of insects according to the key determination of Sharkey (1992) and Wharton and Lopez-Martinez (2000).

The community structure

To determine the community structure, measurements on species diversity index, abundance index and dominance index of parasitoids were applied.

The diversity index was measured using an index developed by Shannon and Wiener (H`) (Magurran 2005), with the following equation:

$$H' = -\sum pi.\,ln.pi$$

Where:
H' : Shannon Wiener Index
ni : Number of species individuals
N : Total number of individuals

The diversity index was grouped into three categories, namely *H'*<1.5 (low diversity), *H*'= 1.5-3.5 (moderate diversity), and H' > 3.5 (high diversity).

The abundance index was measured using the Margalef index (Magurran 2005).

$$R1 = \frac{S-1}{\ln N}$$

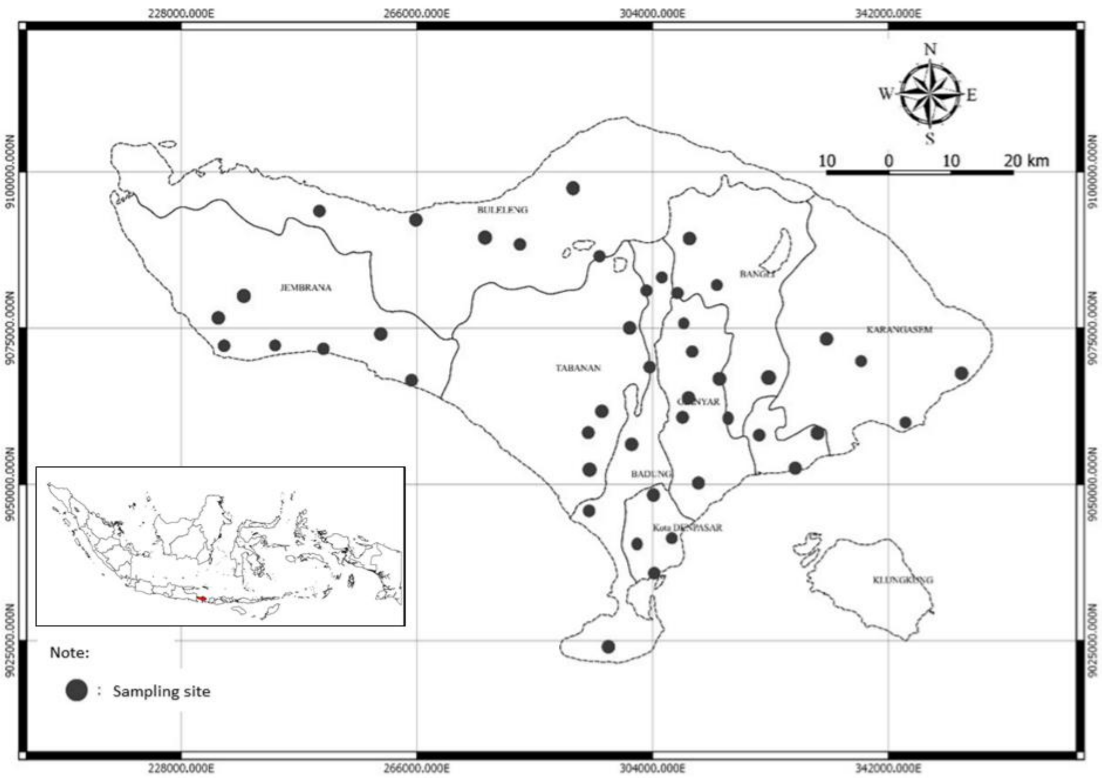

Figure 1. Sampling site in Bali, Indonesia

Where:
R1 : Abundance index
S : Number of species found
ln : Nature logarithm
N : Total number of individuals
Values:
R1 < 3.5 = low
R1 >3.5-<5.0 = moderate
R1 > 5.0 = high

The dominance index was measured using the Menheinick index (Magurran 2005).

$$D = \sum\left(\frac{ni(ni-1)}{N(N-1)}\right)$$

Where:
D : Dominance index
N : Total number of individuals
ni : Number of i-species individuals

Values:
D = ≤ 0.00-0.30: low
D = > 0.30-0.60: moderate
D = ≥ 0.60-1.00: high

Parasitization rate

The parasitization rate was determined by counting the number of flies and adult parasitoids seen in each observation. This was determined using the following formula:

$$P = \frac{\sum adult\ parasitoid\ A}{\sum adult\ S.adipata + \sum adult\ parasitoids\ found} \times 100\%$$

Where:
P = parasitization rate (%)
∑ adult parasitoid A = number of parasitoids
∑ adult *S. adipata* = number of adult *S. adipata*

Data analysis

Morphological characteristics, are presented as images, whereas the community structure and parasitization rate were tabulated and analyzed using Ms. Excel 2019 (Microsoft, USA) and presented in the form of tables and graphs.

RESULTS AND DISCUSSION

There were three species of parasitoid associated with *S. adipata*, which include *Asobara japonica* Belokobylskij, *Fopius arisanus* Sonan, and *Diachasmimorpha longicaudata* Ashmead.

Descriptions and general information

Asobara japonica is distinguished by morphological characteristics such as an antenna that is longer than the body size. As shown in Figure 2A, the body length is 3.87 mm and the antenna length is 3.98 mm. These species have similarities with the parasitoid specimen discovered by Suriani (2020), which has a black ovipositor measuring 2.66 mm in length. Figure 2B shows, species 1 with a dark-brown head and a thorax with a reddish-brown propodeum.

Asobara japonica is a larva-pupae endoparasitoid, with a wide host range, mainly found in larvae of the ~~genus~~ *Drosophila* species, that plays an important role in controlling *Drosophila melanogaster* and *Drosophila suzukii* (Matsumura) (Zhang et al. 2020). This parasitoid can kill the host, causing the parasitoid larvae to die as well (Prevost et al. 2012). Interestingly, this parasitoid can secrete a natural toxin with an atypical effect on the host causing permanent paralysis followed by the death of *D. melanogaster* larvae (Mabiala-Moundoungou et al. 2010). Also, Hymenoptera parasitoids use volatile compounds to locate their hosts, particularly in microhabitat locations. According to the findings of Biondi et al. (2017), the olfactory response of adult *Asobara japonica* illustrates its innate interest or plasticity in exploiting volatile compounds from various fruits infested by the invasive pest *Drosophila suzukii*. The findings of these parasitoid larvae are very helpful in improving protocols for the maintenance and evaluation of *D. suzukii* infesting cherry, blackberry, or strawberry especially in smaller host sizes (Wang et al. 2020; Wang et al. 2021).

Fopius arisanus has a black-brown body with a yellowish-brown abdomen. Furthermore, it has a body length of 4.55 mm, and an antenna length of 5.32 mm, with black color. Also, the ovipositor is 3.46 mm long as shown in Figure 3A. The abdomen is yellowish-brown with a second tergum in a stripe pattern as shown in Figure 3B.a. Furthermore, the mesoscutum is equipped with a notauli shaped like a necklace as shown in Figure 3C.a and Figure 3C.b.

Fopius arisanus is an egg-larva parasitoid that has been widely developed for its potential in biological control programs against the main tephritid pests in fruit commodities, including *Bactrocera dorsalis* (Hendel) and *Ceratitis capitata* (Wiedemann) (Groth et al. 2016). In addition, it was also able to parasitize one-day-old *Ceratitis cosyara* eggs (Karlsson et al. 2018). Furthermore, *F. arisanus* has a haplodiploid mating system, which involves mating with male offspring from unfertilized eggs and females from eggs fertilized by male sperm. On a larger scale, the release of *F. arisanus* was carried out due to its polyphagous nature and bulk compatibility in controlling fruit fly infestations. (Vargas et al. 2012a).

Diachasmimorpha longicaudata, which exhibit a body length of 4.69 mm, is the subject of Specimen 3. It has a bright orange body with a black-brown tarsus. Also, as shown in Figure 4A.a, the antenna is 6.4 mm long and has a dark ovipositor that is 5.5 mm or longer than the body size. As illustrated in Figure 4B, the mesoscutum lacks notauli, whereas the propodeum is orange.

Diachasmimorpha longicaudata (Hymenoptera: Braconidae) is a solitary coinobiont endoparasitoid wasp that lays its eggs in fruit fly larvae where it grows to adulthood (Koskinioti et al. 2020). This is considered as one of the potentials for good biocontrol as an augmentative application against Tephritidae fruit flies. For example, *D. longicaudata* controlling populations of *C. capitata* (Sánchez et al. 2016; Harbi et al. 2018), *B. dorsalis* (Vargas et al. 2012b), *Bactrocera oleae* (Rossi) (Sime et al. 2008), and *B. zonata* (Saunders) (Andleeb et al. 2010). Similarly, *D. longicaudata* is an effective biological control agent against medflies, which infests peach, as well as sour and sweet orange (Suárez et al. 2019).

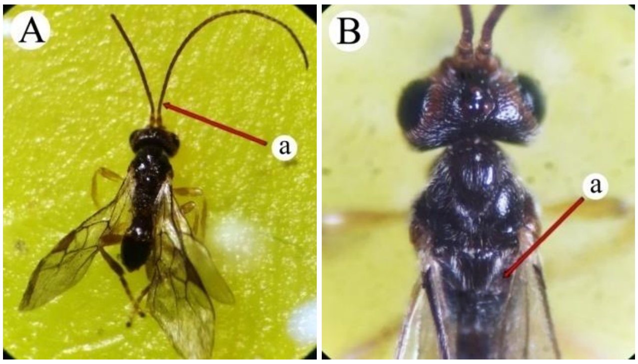

Figure 2. Specimen 1 of *A. japonica*. A. overall appearance (a. antennae) and B. thorax (a. propodeum)

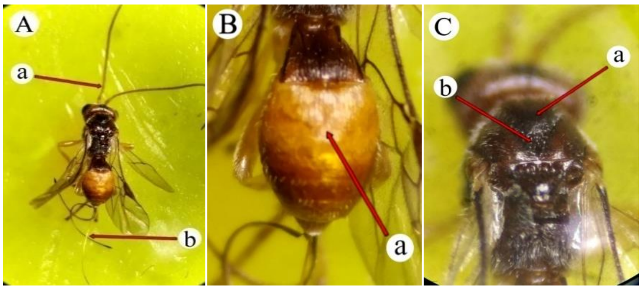

Figure 3. *Fopius arisanus*. A. overall appearance (a. antennae; b. ovipositor). B. Abdomen (a. tergum II). C. Thorax (a. Mesoscutum; b. Notauli).

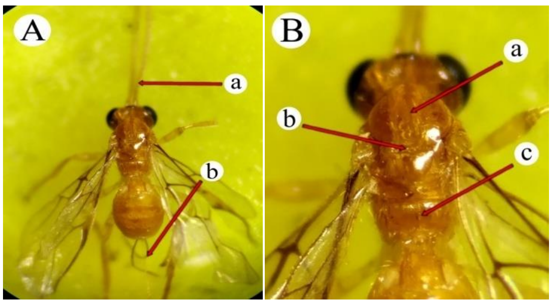

Figure 3. Specimen 3, *Diachasmimorpha laungicaudata*. A. overall appearance (a. antennae; b. ovipositor). B. Thorax (a. Mesoscutum; b. no notauli; c. propodeum)

Silba adipata versus parasitoids in Bali

All recovered Bracondidae species had different diversity, abundance, and dominance index values. The parasitoids associated with *S. adipata* had a "low" abundance index (*H'*<3.5) in all districts and city in Bali with an average abundance index ranging between 0.00-0.76. The parasitoids had a "low" diversity index less than (*H'* <1.0) in all districts and city in Bali with an average diversity index of 0.00-1.02. Meanwhile, there were various dominance index values. The "moderate" dominance index (0.30 < D < 0.60) was found in Badung, Bangli, Gianyar, Karangasem, Klungkung and Denpasar with an average value of 0.37-0.55. While the high dominance index value *(D*>0.60) was found in Buleleng, Jembrana, and Tabanan (0.63-1.00) (Table 1).

Braconidae parasitoids are parasitoids that attack larvae in fruit and are a viable potential for biological control for several reasons. First, natural enemies were able to suppress the population of *S. adipata* cayenne pepper in the field. Second, ecosystems that are rarely touched by human activities and production inputs in agricultural cultivation are actually considered to have high levels of biodiversity in some areas (Wahyuni et al. 2017). Third, genetic resistance, sex ratio, and parasitoid adaptability are also able to determine this (Supartha et al. 2021).

Distribution of *S. adipata* parasitoids in Bali

According to the results, *D. laungicaudata* and *F. arisanus* are both associated with *S. adipata* and were found in all districts and city throughout Bali. *F. arisanus* was not found in Jembrana, whereas *A. japonica* was only found in Badung, Bangli, Gianyar, and Klungkung as shown in Figure 4. In addition, several factors influence parasitoid distribution, including biotic and abiotic factors (Supartha et al. 2020; Yudha et al. 2020).

The parasitization rate of *S. adipata* parasitoids in Bali

The following parasitization rate by *D. longicaudata* per locality was obtained: Karangasem, Tabanan, Jembrana, and Denpasar as 28.18%, 26.56%, 23.21%, and 11.53%, respectively. While that of Klungkung, Buleleng, Bangli, Gianyar and Badung were 10.10%, 6.06%, 5.54%, 4.82% and 4.17%, respectively. Furthermore, the parasitization rate of *F. arisanus* in Karangasem, Gianyar, Denpasar, Bangli, and Buleleng was 16.06%, 7.71%, 5.71%, 3.81%, and 3.57%, respectively. While that of Klungkung, Tabanan, Badung, and Jembrana were 3.03%, 2.46%, 2.04%, and 0.00%, respectively. The parasitization rate by *A. japonica* in Bangli, Klungkung, Badung, and Gianyar was 1.37%, 1.01%, 0.86%, and 0.71%, respectively, whereas, Buleleng, Jembrana, Karangasem, Tabanan, and Denpasar were all at 0.00%, as shown in Figure 6.

Table 1. Community structure of parasitoid *Silba adipata* in Bali, Indonesia

Spesies	District/ City								
	Badung	Bangli	Buleleng	Denpasar	Gianyar	Jembrana	Karangasem	Klungkung	Tabanan
D. longicaudata	60	43	17	4	25	4	15	10	18
F. arisanus	31	34	1	2	80	0	7	3	6
A. japonica	13	15	0	0	17	0	0	1	0
N *parasitoid*	104	92	18	6	122	4	22	14	24
N *S. adipata*	1314	878	322	29	611	14	26	90	509
S parasitoid	3	3	2	2	3	1	2	3	2
S *S. adipata*	1	1	1	1	1	1	1	1	1
R1	0,43	0,44	0,35	0,56	0,42	0,00	0,32	0,76	0,31
H'	0,94	1,02	0,21	0,64	0,88	0,00	0,63	0,76	0,56
D	0,43	0,37	0,89	0,47	0,49	1,00	0,55	0,53	0,63

Note: *N*: Individual abundance, *S*: Species abundance, *R1*: Abundance Index, *H'*: Diversity index, *D*: Dominance Index.

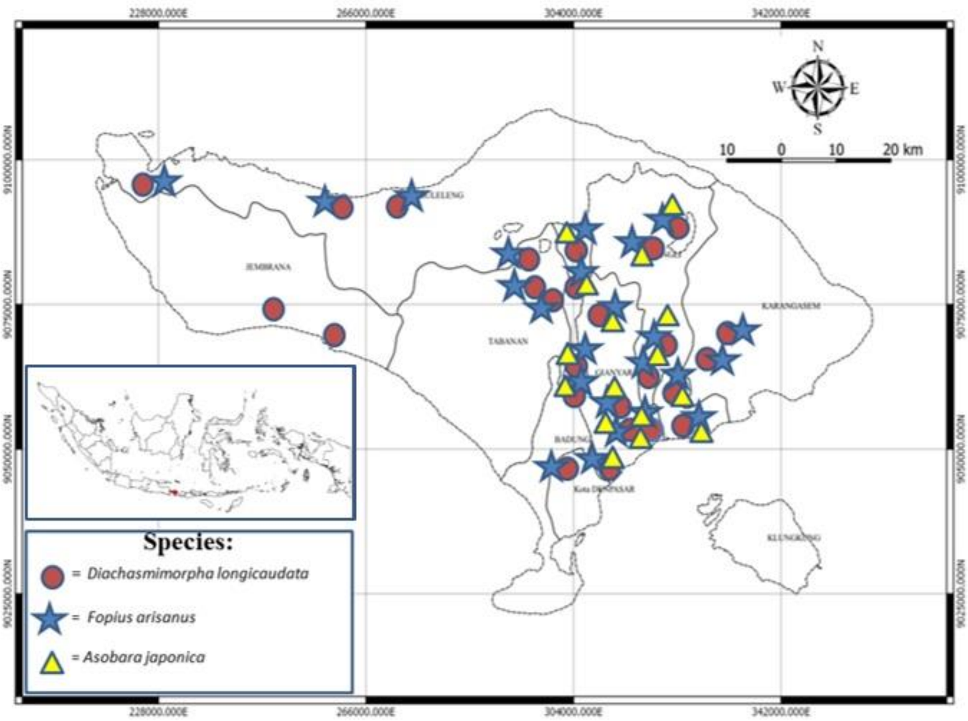

Figure 5. The map distribution of *Silba adipata* parasitoid in Bali, Indonesia

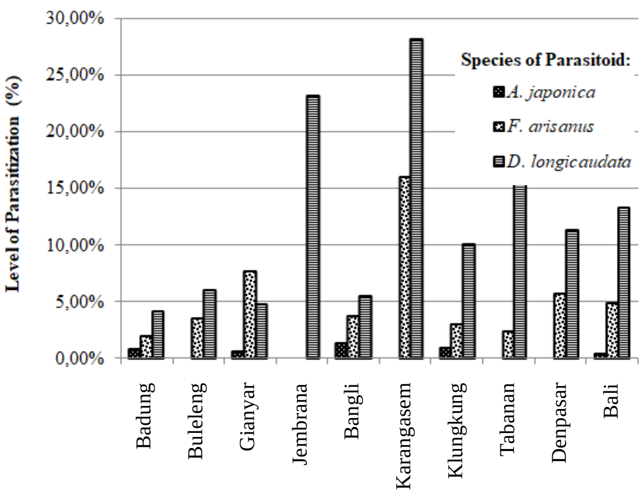

Figure 6. Parasitization rate of three parasitoids (Braconidae) on *Silba adipata* in Bali, Indonesia

In the present study, *D. longicaudata* had the highest potential to control *S. adipata* infestations in cayenne pepper in Bali. The parasitization rate tends to be directly proportional to the host population, and vice versa since the host population decreases with the number of parasitoids (Cusumano and Volkoff. 2021). Meanwhile, preference factors for other types of host prey, as well as demographic changes, can influence the natural decrease in parasitism rates (Papkou et al. 2016). Furthermore, competition between species within the same host promotes the survival of other types of parasitoids (Yang et al. 2013).

Biological control of *S. adipata* using parasitoids is a strategic effort through the introduction of exotic parasitoids (classical biological control) and alternative uses of ecologically based insecticides (Sow et al. 2019). Keseluruhan, parasitoid ini adalah endoparasitoid soliter yang mampu menyerang bagian telur/larva (Wang et al. 2021).

Diachasmimorpha laungicaudata had the highest parasitization rate of 28.18%, compared with *F. arisanus* and *A. japonica* (16.06 % and 1.37%, respectively). Overall, our results reveal preliminary information about the parasitoid diversity associated with the new invasive pest *S.~~ilba~~ adipata* in Cayenne Pepper in Bali. Further studies are still needed to evaluate the efficacy of release of exotic-parasitoids to control *S. adipata.*

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