

Original Article

## Distribution, abundance and seasonality of scale insects in sugarcane crops in the state of São Paulo

Distribuição, abundância e sazonalidade de cochonilhas em culturas de cana-de-açúcar no estado de São Paulo

G. G. Monteiro<sup>a\*</sup> , A. L. B. G. Peronti<sup>b</sup>  and N. M. Martinelli<sup>a</sup> 

<sup>a</sup>Universidade Estadual Paulista – UNESP, Faculdade de Ciências Agrárias e Veterinárias, Departamento de Ciências da Produção Agrícola (Fitossanidade), Laboratório de Biosistemática de Hemiptera, Jaboticabal, SP, Brasil

<sup>b</sup>Autônomo, São Carlos, SP, Brasil

### Abstract

In the state of São Paulo, the main sugarcane producing region of the world, two species of scale insects have frequently occurred, *Aclerda takahashii* (Kuwana, 1932) (Hemiptera: Acleridae) and *Saccharicoccus sacchari* (Cockerell, 1895) (Hemiptera: Pseudococcidae). To map the distribution and abundance of these species, 17 sugarcane producing fields, distributed in six mesoregions in São Paulo, were evaluated in August 2017 and, January, February, June and July 2018 during the ripening phase. The study on the seasonality of these species, by the presence or absence of the scale insects during the phenological cycle of the plant, was conducted between August 2017 and July 2018 in two sugarcane producing fields in the municipality of Jaboticabal, São Paulo, Brazil. The presence of *S. sacchari* was found in all the analyzed locations, and *A. takahashii* in twelve. Both scale insects showed significant difference of infestation in the node's region of the stems during the ripening phase in one of the studied locations. The aclerdid presented significant difference by infestation in one site during the ripening phase of the plant. The pseudococcid infested a greater number of nodes in the following phases of development; vegetative, grand growth and ripening in both studied areas, but it was in one site during the ripening phase that presented the greatest difference. Although the pink sugarcane mealybug was more abundant than *A. takahashii* in both studies, there were no patterns of relationships between the numbers of individuals to geographical locations and temperature.

**Keywords:** *Aclerda takahashii*, dispersion, population fluctuation, *Saccharicoccus sacchari*.

### Resumo

No estado de São Paulo, principal região produtora de cana-de-açúcar do mundo, duas espécies de cochonilhas têm ocorrido frequentemente, *Aclerda takahashii* (Kuwana, 1932) (Hemiptera: Acleridae) e *Saccharicoccus sacchari* (Cockerell, 1895) (Hemiptera: Pseudococcidae). Para mapear a distribuição e abundância destas espécies, 17 regiões produtoras de cana-de-açúcar, distribuídas em seis mesorregiões de São Paulo, foram avaliadas em agosto de 2017 e janeiro, fevereiro, junho e julho de 2018, durante a fase de maturação. O estudo da sazonalidade destas espécies, pela presença ou ausência das cochonilhas durante o ciclo fenológico da planta, foi conduzido entre agosto de 2017 e julho de 2018 em duas regiões produtoras de cana-de-açúcar no município de Jaboticabal, São Paulo, Brasil. *Saccharicoccus sacchari* foi encontrada em todas as localidades analisadas, e *A. takahashii* em 12. Ambas cochonilhas mostraram diferença significativa de infestação na região dos nós dos colmos durante a fase de maturação em uma das localidades estudadas. O aclerdídeo apresentou diferença significativa pela infestação em uma localidade durante a fase de maturação da planta. O pseudococídeo infestou um grande número de nós nas seguintes fases de desenvolvimento; perfilhamento, crescimento vegetativo e maturação em ambas áreas estudadas, mas foi em uma localidade durante a fase de maturação que apresentou a maior diferença. Embora a cochonilha rosada da cana-de-açúcar foi mais abundante do que *A. takahashii* em ambos estudos, não houve padrões de relações entre o número de indivíduos com a localização geográfica e temperatura.

**Palavras-chave:** *Aclerda takahashii*, dispersão, flutuação populacional, *Saccharicoccus sacchari*.

### 1. Introduction

In Brazil 18 species of scale insects associated to sugarcane were reported, of which *Aclerda takahashii* (Kuwana, 1932) (Acleridae) and *Saccharicoccus sacchari*

(Cockerell, 1895) (Pseudococcidae) has been the most widely distributed (Silva et al., 1968; Oliz and Wolff, 2014; Zhang et al., 2018).

\*e-mail: gabrielmonteiro7777@hotmail.com

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*Aclerda takahashii* originated in Asian, was described from specimens collected in Taiwan (Kuwana, 1932). Currently, this species occurs in 13 countries distributed in the zoogeographical regions: (1) Nearctic, (1) Palearctic, (1) Neotropical, (8) Oriental and (2) Ethiopian (Morales et al., 2016). The acletrid is associated to grassy plants of the genera *Agropyron*, *Brachypodium*, *Milium*, *Miscanthus*, *Saccharum*, *Stipa* and *Thysanolaena* (Morales et al., 2016).

In South America, *A. takahashii* is restricted to Brazil, where was first reported in the state of São Paulo, in 1932 (Silva et al., 1968), the largest sugarcane producer in the world (Embrapa, 2020). Later it was spread to the states of Pernambuco, Alagoas, Espírito Santo, Rio de Janeiro and Rio Grande do Sul and in the Federal District (Oliz and Wolff, 2014; Morales et al., 2016).

Information on this acletrid is based on its original description (Kuwana, 1932), immature stages (Karam, 1991) and distribution (McConnell, 1954; Muniappan, 2001; Oliz and Wolff, 2014). According to Lim and Pan (1976), injuries are relatively non-damaging to sugarcane. However, in Guam island on vetiver plants, *Vetiveria zizanioides* (Linnaeus) (Poales: Poaceae), infested by this insect, necrosis and discoloration on the stem and large amount of fumagine on the honeydew were observed (Muniappan, 2001).

*Saccharicoccus sacchari* was described from specimens collected in Trinidad and Tobago (Cockerell, 1895), however there are still doubts about its possible center of origin (Zhang et al., 2018). This species is widely distributed, 79 countries distributed in six zoogeographical regions: (3) Nearctic, (5) Palearctic, (34) Neotropical, (13) Oriental, (14) Ethiopian and (10) Australian (Morales et al., 2016). The pseudococcid was registered on 18 host plants distributed in the families: Arecaceae, Caricaceae and Poaceae, been more frequently mentioned on sugarcane (Morales et al., 2016).

In Brazil, this species was reported in the states of Amazonas, Pará, Paraíba, Pernambuco, Minas Gerais, Mato Grosso, Rio de Janeiro, São Paulo and Santa Catarina (Silva et al., 1968; Morales et al., 2016).

Under laboratory conditions, the pseudococcid has four to five generations per year; with shorter life cycles when reared at 20 °C (Kalra and Sidhu, 1964). In India, its presence in sugarcane slowed the growth of the plant, and caused the death of newly planted sheets (Yakoub, 2012). This insect can also cause a reduction in stem diameter and weight, and reduction in sugar by up to 21%, in addition to acting as a vector for the bacilliform sugarcane virus (BSCV) (Atiqui and Murad, 1992; Mohamed et al., 2009; Victoria et al., 2005).

*Aclerda takahashii* and *S. sacchari* preferentially infest the region nodes of the stem, under the leaf sheath (Bonnett and Hewitt, 2005; Stocks, 2016). In addition, the pseudococcid can infest the roots (Kalra and Sidhu, 1964; Inkerman et al., 1986; Bonnett and Hewitt, 2005). Inkerman et al. (1986) described that the nymphs reach the aerial part of the plant, after their sprouting, settling in the region nodes under the sheaths.

Due to this cryptic habit, scale insects are rarely dispersed through wind or water, and their control becomes difficult (Rajendra, 1974; Inkerman et al., 1986;

Qin et al., 2017). However, in this case, ants play an important role, as they feed on excreted honeydew and carry them to neighboring plants (Rajendra, 1974). Other ways of dispersion may be due to agricultural practices, such as jet-transported equipment (Inkerman et al., 1986). The pseudococcid can also be dispersed by planting nymph-infested sheets (Inkerman et al., 1986).

Probably due to its greater distribution in the globe, *S. sacchari* has been better studied in relation to bioecological aspects, as well as its impacts on sugarcane fields (Atiqui and Murad, 1992; Mohamed et al., 2009; Victoria et al., 2005; Zhang et al., 2018). The population dynamics of this insect was studied in Australia during a five-year period, 1999 to 2003 (Bonnett and Hewitt, 2005). These authors found that in the months of January and February, corresponding to the end of summer, there were greater population peaks, varying from one year to another, and among the different studied sites. Bonnett and Hewitt (2005) attributed these irregularities to climatic conditions, the warmer months, and to different agricultural practices in the studied regions.

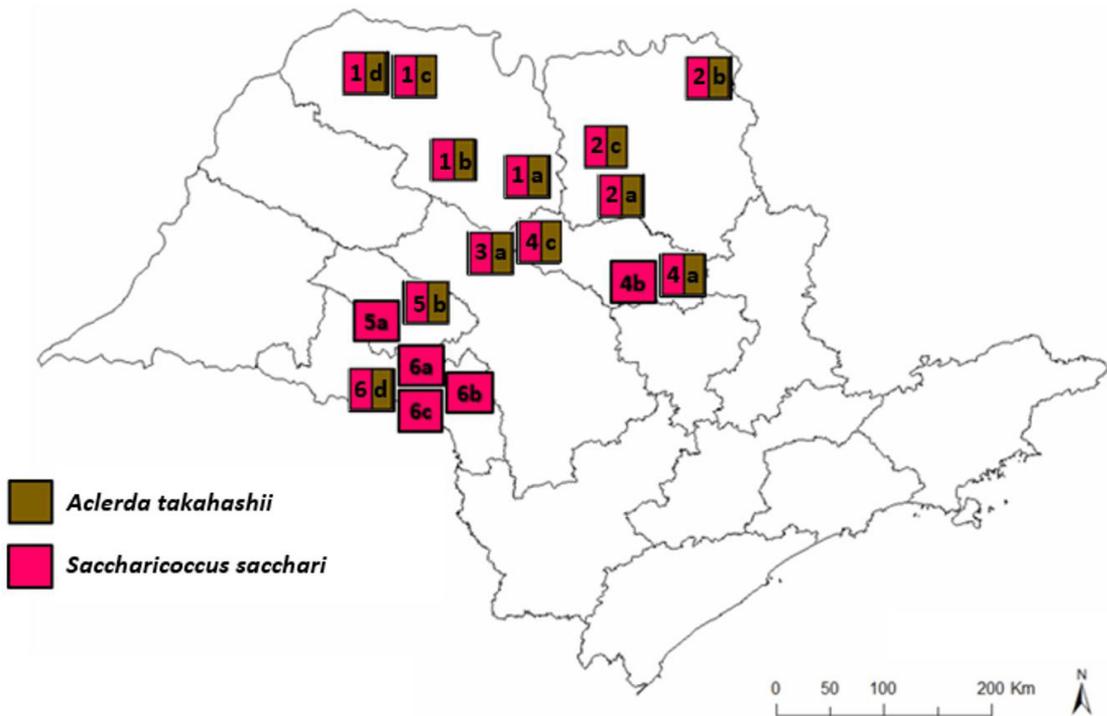
Knowledge about the occurrence and distribution of pest species in a given geographical location is of great importance, as legal measures can be taken to prevent their transport to free areas of these organisms. However, studies on its seasonality and population density, in a given region, are fundamental for the establishment of action related to integrated pest management.

Therefore, this study analyzed the distribution and abundance of *A. takahashii* and *S. sacchari* in sugarcane plants in the ripening phase in the state of São Paulo, and the seasonality of both species by the presence of them in all phenological phases in two sites in Jaboticabal, São Paulo, Brazil.

## 2. Material and Methods

### 2.1. Studied areas

The distribution and abundance of the scale insects were analyzed in 17 sugarcane producing fields, distributed in six mesoregions in the state of São Paulo, Brazil (Figure 1). The evaluations were carried out in the months of August 2017, and January to March and June and July 2018, corresponding to the ripening phase of the crop, before harvest. The locations are followed by the coordinates; (1) mesoregion of São José do Rio Preto (Pindorama -21°24'36" S, -48°89'34" W, altitude of 527 m; Nova Aliança -21°00'86" S, -49°50'68" W, altitude of 464 m; Votuporanga -20°43'94" S, -50°00'69" W, altitude of 525 m; Jales -20°28'10" S, -50°52'49" W, altitude of 478 m), (2) mesoregion of Ribeirão Preto (Jaboticabal -21°23'44" S, -48°34'08" W, altitude of 605 m; Franca -20°59'66" S, -47°39'97" W, altitude 1040 m; Taquaral -21°07'54" S, -48°40'21" W, altitude of 643 m), (3) mesoregion of Bauru (Pongá -21°74'33" S, -49°35'16" W, altitude of 422 m), (4) mesoregion of Araraquara (Água Vermelha -21°90'10" S, -47°88'85" W, altitude of 729 m; São Carlos -22°08'10" S, -47°89'48" W, altitude of 856 m; Itápolis -21°58'90" S, -48°82'92" W, altitude of 487 m), (5) mesoregion of



**Figure 1.** Distribution of *Aclerda takahashii* (12) and *Saccharicoccus sacchari* (17) in locations in the state of São Paulo, Brazil. Legend – (1a) Pindorama, (1b) Nova Aliança, (1c) Votuporanga, (1d) Jales; (2a) Jaboticabal, (2b) Franca, (2c) Taquaral; (3a) Pongai; (4a) São Carlos, (4b) Água Vermelha, (4c) Itápolis; (5a) Echaporã, (5b) Marília; (6a) Platina, (6b) Palmital, (6c) Cândido Mota, (6d) Assis.

Marília (Echaporã  $-22^{\circ}47'29''$  S,  $-50^{\circ}32'32''$  W, altitude of 700 m; Marília  $-22^{\circ}09'26''$  S,  $-49^{\circ}90'20''$  W, altitude of 660 m), and (6) mesoregion of Assis (Platina  $-22^{\circ}62'87''$  S,  $-50^{\circ}20'19''$  W, altitude of 466 m; Palmital  $-22^{\circ}77'94''$  S,  $-50^{\circ}22'88''$  W, altitude of 508 m; Cândido Mota  $-22^{\circ}73'55''$  S,  $-50^{\circ}37'42''$  W, altitude of 479 m; Assis  $-22^{\circ}65'04''$  S,  $-50^{\circ}36'97''$  W, altitude of 543 m).

For the seasonality study, monthly collections of scale insects were made between August 2017 and July 2018, in two sugarcane producing fields, located in the municipality of Jaboticabal, São Paulo, Brazil, followed by the coordinates; (site 1)  $-21^{\circ}13'22''$  S,  $-48^{\circ}16'81''$  W, altitude of 608 m, and (site 2)  $-21^{\circ}17'31''$  S,  $-48^{\circ}18'63''$  W, altitude of 614 m. All phenological phases of the plant, under the same clumps, were evaluated.

## 2.2. Experimental design

To dimension the species in the sugarcane producing fields in the state of São Paulo, an adapted technique described by Bonnett and Hewitt (2005) was used. Ten sugarcane plants from the edge of the crop, cultivar RB86 7515, five meters apart from each other, were randomly selected and evaluated. The leaves were tilted until the stem area was exposed, making it possible to observe the individuals with the naked eye. The nodes of the stem infested by scales insects were counted, observing the presence or absence of *A. takahashii* and *S. sacchari*, in the phases of the third instar nymph and adult.

For the evaluation of the statistical analysis, the data were submitted in completely randomized design (CRD) with 17 treatments and 10 replicates for the analysis of distribution and abundance of scale insects in the sugarcane producing fields on ripening phase distributed in the state of São Paulo, Brazil, and 12 treatments and 10 replicates for the analysis of the seasonality of scale insects in all phenological phases of the plants in each site in the municipality of Jaboticabal, São Paulo, Brazil, for each species. The program used was SAS® University Edition, version 9.4. The data, number of nodes infested with scale insects were submitted to Bartlett's tests to verify homocedasticity (PROC GLM) and Cramer von Mises's test for normality (PROC UNIVARIATE). The data showed normality in this way the Analysis of Variance (PROC ANOVA) was conducted. The means (PROC MEANS) when significant were compared using the Tukey test ( $p < 0.05$ ) (Everitt and Hothorn, 2005).

## 2.3. Identification and deposit of voucher species

To confirm the species, samples were collected in the field and mounted on permanent slides using the technique described by Willink (1990). The identification took place under an optical microscope through morphological characteristics using the works of McConnell (1954) for *A. takahashii* and Williams and Willink (1992) for *S. sacchari*.

The voucher species were deposited in the Reference Collection of Insects and Mites (CRIA) of the Department

of Agricultural Production Sciences of the FCAV/UNESP, Jaboticabal, São Paulo, Brazil.

### 3. Results

#### 3.1. Distribution and abundance of *Aclerda takahashii* and *Saccharicoccus sacchari*

*Saccharicoccus sacchari* was best distributed, being present in all locations in the state of São Paulo, while *A. takahashii* was observed in 12 (see Figure 1).

Regarding the abundance of species in the evaluated sugarcane producing fields, *A. takahashii* infested 2.6 nodes in São Carlos, providing statistical difference for the other locations that did not differ from each other (as shown in Table 1).

The population of *Saccharicoccus sacchari* differed in high incidence in Votuporanga, infesting 3.0 nodes of the analyzed plants (as shown in Table 1).

#### 3.2. Seasonality of *Aclerda takahashii* and *Saccharicoccus sacchari*

Regarding the two analyzed sugarcane producing fields in Jaboticabal, the population of *A. takahashii* was more abundant in site 1, in March 2018, ripening phase (see Figure 2). The aclerdid infested 0.5 nodes of the plants, with a significant difference for the other analyzes that did not differ from each other (as shown in Table 2).

The pseudococcid was more abundant in site 2 in August 2017, ripening phase (see Figure 3). *Saccharicoccus*

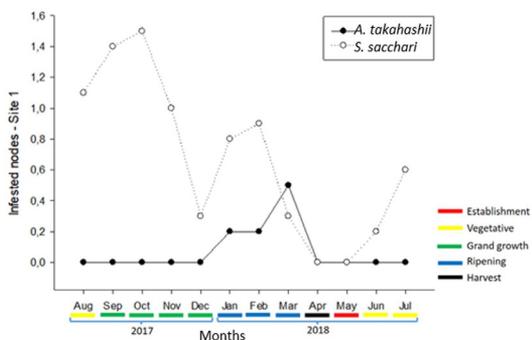


Figure 2. Infested nodes for both species in the site 1 in the phenological of sugarcane plants.

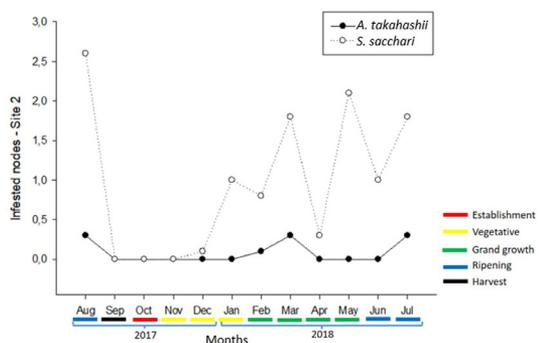


Figure 3. Infested nodes for both species in the site 2 in the phenological of sugarcane plants.

Table 1. Infested nodes with scale insects, by locations in the state of São Paulo, Brazil, in the ripening phase.

Locations	<i>Aclerda takahashii</i>	<i>Saccharicoccus sacchari</i>
Pindorama	0.9 ± 0.27ac*	0.3 ± 0.21c*
Nova Aliança	0.2 ± 0.13a	0.6 ± 0.26c
Votuporanga	1.3 ± 0.51ac	3.0 ± 0.39b
Jales	1.3 ± 0.51ac	1.0 ± 0.36c
Água Vermelha	0.0 ± 0.00a	0.9 ± 0.27c
São Carlos	2.6 ± 0.65b	2.5 ± 0.63ab
Platina	0.0 ± 0.00a	0.3 ± 0.15c
Palmital	0.0 ± 0.00a	0.3 ± 0.15c
Cândido Mota	0.0 ± 0.00a	0.7 ± 0.21c
Assis	0.1 ± 0.10a	0.9 ± 0.23c
Echaporã	0.0 ± 0.00a	1.6 ± 0.33ac
Marília	0.2 ± 0.13a	1.5 ± 0.34ac
Pongaí	1.8 ± 0.41c	1.6 ± 0.37ac
Itápolis	0.3 ± 0.15a	1.5 ± 0.22ac
Jaboticabal	0.3 ± 0.21a	2.5 ± 0.34ab
Franca	0.1 ± 0.10a	0.6 ± 0.26c
Taquaral	0.0 ± 0.00a	0.6 ± 0.22c

*Aclerda takahashii* (F = 0.52; df = 16; p < 0.001); *Saccharicoccus sacchari* (F = 2.18; df = 16; p < 0.001). \*Means ± standard error followed by the same letter in the same column do not differ by Tukey test (p > 0.05).

**Table 2.** Infested nodes with scale insects, by sites in the municipality of Jaboticabal, São Paulo, Brazil.

Period	<i>Aclerda takahashii</i>		<i>Saccharicoccus sacchari</i>	
	Site 1	Site 2	Site 1	Site 2
Aug/17	0.0 ± 0.00b*	0.3 ± 0.21a*	1.1 ± 0.27ab*	2.6 ± 0.33b*
Sep/17	0.0 ± 0.00b	0.0 ± 0.00a	1.4 ± 0.33b	0.0 ± 0.00c
Oct/17	0.0 ± 0.00b	0.0 ± 0.00a	1.5 ± 0.26b	0.0 ± 0.00c
Nov/17	0.0 ± 0.00b	0.0 ± 0.00a	1.0 ± 0.25abc	0.0 ± 0.00c
Dec/17	0.0 ± 0.00b	0.0 ± 0.00a	0.3 ± 0.15ac	0.1 ± 0.10c
Jan/18	0.2 ± 0.13b	0.0 ± 0.00a	0.8 ± 0.24abc	1.0 ± 0.42ac
Feb/18	0.2 ± 0.13b	0.1 ± 0.10a	0.9 ± 0.31abc	0.8 ± 0.35ac
Mar/18	0.5 ± 0.22a	0.3 ± 0.21a	0.3 ± 0.15ac	1.8 ± 0.55ab
Apr/18	0.0 ± 0.00b	0.0 ± 0.00a	0.0 ± 0.00c	0.3 ± 0.21c
May/18	0.0 ± 0.00b	0.0 ± 0.00a	0.0 ± 0.00c	2.1 ± 0.48ab
Jun/18	0.0 ± 0.00b	0.0 ± 0.00a	0.2 ± 0.13ac	1.0 ± 0.25ac
Jul/18	0.0 ± 0.00b	0.3 ± 0.21a	0.6 ± 0.26abc	1.8 ± 0.44ab

*Aclerda takahashii* Site 1 (F = 0.63; df = 11; p < 0.001), Site 2 (F = 1.04; df = 11; p < 0.001); *Saccharicoccus sacchari* Site 1 (F = 3.31; df = 11; p < 0.001), Site 2 (F = 4.06; df = 11; p < 0.001). Means ± standard error followed by the same letter in the same column do not differ by Tukey test (p > 0.05).

*sacchari* infested 2.6 nodes, but there were no significant differences among analyzes (as shown in Table 2).

#### 4. Discussion

*Saccharicoccus sacchari* was found to be better distributed and infesting more nodes in the sugarcane fields in the state of São Paulo compared to *A. takahashii*. Although the acclerid was registered in a few locations as to the pseudococcid, it was at least found in one location in each geopolitical mesoregion in the state of São Paulo.

The wider distribution and quantity of infested nodes found for *S. sacchari* in relation to *A. takahashii* may be related mainly to its more efficient dispersion. The pseudococcid can survive on newly-planted and/or cut sheets, having been observed infesting sheets at a depth of 30 centimeters (Sartiani et al., 2017). These, before migrating to the aerial part of the plants, can also infest the roots; whereas *A. takahashii* has been observed only in the node's regions, in the aerial part of *Saccharum* spp. (Oliz and Wolff, 2014). In addition, *S. sacchari* apparently produces more honeydew than *A. takahashii*, probably attracting a greater number of protective ants against natural enemies. However, for both species Cruz et al. (2019) found a significant number of associated natural enemies, ten for *A. takahashii* and 12 for *S. sacchari*.

As for the seasonality of the two species in the municipality of Jaboticabal, São Paulo, Brazil, the most abundantly recorded specimens show an appearance pattern at the phenological phases of the plants. In site 1, the acclerid was more present in the month of March 2018, referring to the phenological phase of ripening, and in site 2, there was no significant difference in appearance, however its greatest record was found in the same period, however plants in the intermediate phenological phase of grand growth. In turn, the pink sugarcane mealybug on

site 1, infested more nodes in the months of September and October 2017, with plants referring to the initial phenological phase of grand growth, while on site 2, its greatest record was in the final phenological phase of ripening, preceding the harvest. According to INMET (2018) the sugarcane producing fields of Jaboticabal presented, at the time of analysis, precipitation 0 mm, and average temperature of; 15.6 °C, 16.6 °C, 20.0 °C and 19.4 °C, consecutively for the months of August, September and October 2017 and March 2018. Although there is no information on the optimal temperature for the development of *A. takahashii*, however *S. sacchari*, according to Kalra and Sidhu (1964), the optimal reproduction temperature of the species is 20 °C, which may have favored its registration in these locations. However, studies conducted by Bonnett and Hewitt (2005) in Australia did not demonstrate a seasonal distribution relationship, as it was registered that although in summer, the warmest period of the year, which was expected to have the largest population peaks, similar to what was observed in this study, populations of both lower species in relation to the months of December 2017 and January and February 2018. During this period, the rains probably may have influenced the population dynamics of this species, since the plant accumulates water in the sheath, causing the scale insects to be killed by being immersed part of the time, or by the action of entomopathogenic fungi that are favored due to the high humidity. According to Mora-Lugo et al. (2015), entomopathogenic fungi as those of the genus *Aspergillus* are easily found in natural environments, and these infect scale insects, causing their death. However, the study does not present a relation of population dynamics of the species, favored or not by precipitation and average temperature.

The life cycle of insects is interrupted during the harvest period that occurs once a year, usually in the months of April and September. Therefore, the differences among the abundances for both species between the sampling sites in

the municipality of Jaboticabal throughout the study period can be attributed to the different periods of harvest at the sites. For site 1, the harvest was in April 2017; and to site 2, in September of the same year. In the harvest months and the two subsequent months, scale insects were not counted because they were absent. Although there is no information on the underground habit of *A. takahashii*, according to Kalra and Sidhu (1964) after the sugarcane harvest, the pink sugarcane mealybug survives at the root, under the soil, and as the plant grows, the mealybug will spread to the stem when they are ripe for sap sucking.

*Aclerda takahashii* and *S. sacchari* are widely distributed in the state of São Paulo, and although the pseudococcid has infested more nodes in the stems than the aclerdid, in both studies, there were no population dynamics relationships of both species to geographical locations and temperature.

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