Pontificia Universidad JAVERIANA Bogotá

Univ. Sci. 25 (2): 175-200, 2020.
doi: 10.11144/Javeriana.SC25-2.ialh

ORIGINAL ARTICLE

Identification and life history of aphids associated with chili pepper crops in southwestern Colombia

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Received: 20-08-2019
Accepted: 17-04-2020
Published on line: 10-06-2020

Abstract

Viral diseases, transmitted by aphids, are the most limiting problems in chili pepper crops. Understanding the demographic features of these aphids, may thus assist the design of better disease control strategies in chili peppers. Aphid species found in chili pepper crops in southwestern Colombia were identified as *Aphis gossypii* Glover and *Myzus persicae* (Sulzer). An array of life-history parameters of both aphid species were investigated at 25 °C ± 0.5, 75 ± 1.75 % r.h., L12:D12, and LS 5-Light Storm in chili pepper crops. Both aphid populations consisted only of parthenogenetic females, showing a similar average development time—from the first nymphal instar to the post-reproductive adult—, female longevity, and daily average fertility values. The length of the reproductive period was higher for *M. persicae*. *A. gossypii* reached its adult state significantly faster than *M. persicae*. The intrinsic rate of population growth (r_m) was lower for *M. persicae* (0.39) compared to *A. gossypii* (0.43). Results showed a potential for fast population growth in both species, which would enhance their role as virus vectors. The information acquired is essential to develop pest management initiatives for these two aphid species.

Keywords: *Aphis gossypii*, Barcoding, *Capsicum*, *Myzus persicae*, r_m values.

Introduction

Chili pepper viral diseases, caused by Potyvirus, Cucumovirus, and Poleovirus, are transmitted by several aphid species (Hemiptera: Aphididae) [1] and severely affect crop production; losses may reach 100 % depending on the level disease incidence. Worldwide, 16 aphid species have been specifically reported in chili pepper crops [2]. In Colombia, 3 941 ha are cultivated with

Citation: Tálaga-Taquinas W, Melo-Cerón CI, Lagos-Álvarez YB, Duque-Gamboa DN, Toro-Perea N, Manzano MR. Identification and life history of aphids associated with chili pepper crops in southwestern Colombia, *Universitas Scientiarum,* 25 (2): 175-200, 2020. doi: 10.11144/Javeriana.SC25-2.ialh

Funding:
Universidad Nacional de Colombia -Palmira campus and and Fondo CTeI-Sistema General de Regalías.

Electronic supplementary material:
Supp. 1

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of chili peppers, of which 167 are located in the department of Valle del Cauca (southwestern Colombia) [3]. A fraction of the product is destined to local consumption, and most of it is exported as chili paste. Local chili pepper producers spray insecticides to control both viral symptoms and aphids regardless of aphid species identity. The lack of species-related information on chili pepper aphids hinders the development of proper pest management plans [4].

A precise taxonomic identification of aphids, especially in the field, is challenging because of morphotypes with discreet morphometric differences within the same species [5] and chromatic variations unleashed by environmental stimuli [6] and intrinsic factors such as overpopulation or the type of host [7]. Molecular identification approaches, overcome the difficulties posed by morphological traits in telling aphid species apart. More precisely, the Cytochrome c Oxidase Subunit I (COI) gene region provides barcoding data complementing the morphologic identification of aphid species at any developmental stage [4, 8], namely by discriminating cryptic species [9], allowing the assignment of morphotypes of different development stages within a given species [10], and clarifying the confounding effect of host-related variation among aphid morphotypes [11].

Aphid populations can grow profusely because they exhibit cyclic parthenogenesis which combines sexuality and parthenogenesis, and, depending on crowding conditions or plant quality, they are capable of producing either winged or wingless parthenogenetic females [12]. However, in hot tropical and sub-tropical climates, aphids usually reproduce by thelytokous parthenogenesis [2], resulting in fast population growth. Besides, aphid populations entail overlapping generations, parental groups, as well as their older descendants contribute to population increase [13]. One way to measure the potential population growth of an aphid species is via life tables. These constitute crucial tools to comprehend population dynamics, estimate the insects' potential and reproductive growth parameters [14], which, in turn, influence how aphid-borne viruses spread [15].

To broaden the knowledge about aphids in chili pepper crops in southwestern Colombia, we first identified the aphid species occurring in these crops, using morphological and molecular tools. Next, we established and compared some demographic and life history traits of the aphid species, in the hopes of understanding their impact on aphid-borne virus transmission in chili pepper crops. The results of this study can be applied to develop suitable aphid management plans in chili peppers.

Materials and Methods

Study site

Aphids were sampled in commercial chili pepper crops, including tabasco pepper (*Capsicum frutescens*), cayenne pepper (*Capsicum annuum*), jalapeño pepper (*Capsicum annuum*), and habanero pepper (*Capsicum chinense*) in the valley of the Cauca River (department of Valle del Cauca) Colombia. The crops were located in ten municipalities, with altitudes between 689 and 1 295 meters above sea level, comprising tropical dry forests in alluvial foothills and humid forests in fluvial-gravitational m ountains. The region has an average temperature of 23.3 ± 6 °C, relative humidity of 79 ± 2.4 %, rainfall of 1 313 mm/year, and wind speed of 1.5 m/s. A total of 58 hectares of chili pepper crops were sampled in 29 commercial farms from 18 localities that cultivate tabasco pepper (15 farms, 39 ha), habanero pepper (8 farms, 9 ha), cayenne pepper (4 farms, 7 ha), and jalapeño pepper (2 farms, 3 ha), from October 2015 to October 2017.

Aphid sampling, preservation, and identification

Chili pepper plants of more than 16 months of age were chosen randomly and examined for two hours. Both winged and wingless aphid nymphs and adults were collected. For molecular identification, aphids were deposited immediately in containers with 96 % alcohol and stored at -20 °C. For morphologic identification, adults and nymphs were placed alive in plastic boxes (23 cm × 17 cm × 12 cm) with chili pepper leaves, covered with mesh and transported to the laboratory. Insects for morphological identification were sacrificed in water at 80 °C (to prevent post-mortem aphid melanization) and kept in a 70 % alcohol solution. Subsequently, they were sorted by morphotype and preserved in microscope plates following the modified protocol of Blackman and Eastop [16]. The taxonomic identification was carried out using the keys of Blackman and Eastop [16, 2]. Aphid identification was confirmed by experts at the Entomological Museum of the Universidad Nacional de Colombia in Bogotá, UNAB.

Molecular identification using DNA barcoding

COI gene sequences: To obtain the COI gene sequences, DNA was extracted from 40 aphids of different chili pepper crops (two of *C. frutescens* and two of *C. annuum*), and from 39 aphids representing the different morphotypes under mesh house rearing. DNA was extracted from the entire body of each aphid with the commercial animal tissue kit from QIAGEN, following the manufacturer's recommendations. DNA

quantifications were done with a NanoDrop 2000 spectrophotometer. COI amplification was carried out with the primers described by Folmer *et al*. [17], LCO1490 (5' ggtcaacaaatcataaagatattgg-3') and HCO2198 (5'-taaacttcagggtgaccaaaaaatca-3'), under the amplification conditions used by Duque-Gamboa *et al*. [18]. Amplified products were displayed in agarose gels and sequenced at MACROGEN (Seoul, South Korea). The sequence files obtained were edited and aligned using MEGA6 [19].

Molecular identification of aphid species: Species recognition was carried out employing the neighbor-joining (N-J) grouping method, calculating genetic distances between haplotypes, and comparing the sequences obtained with those reported in public databases [20, 21]. The N-J analysis under the Kimura's two-parameter model (K2P) and 1 000 bootstrap replicates were performed with the purpose of discriminating haplotype clusters and genetic distances among pairs of haplotypes within every cluster. Sequences showing genetic intra-group distances below 2 % were assigned to the same taxonomic unit. Interspecific genetic distances were estimated among clusters. All DNA sequence analyses were done with the software MEGA6 [19]. Finally, the sequences of different taxonomic units were compared with the ones available in the BOLD public databases (Barcode of Life Data Systems) and NCBI (National Center for Biotechnology Information), which allowed for species identification [22, 20]. Each reared aphid stage and the morphotypes found due to polychromy, during their immature development, were identified via COI gene sequencing. Three specimens were used per morphological form and color, adding to 33 COI gene sequences for *A. gossypii*. Individuals of *M. persicae* showed a stable coloration pattern during their development period and six COI gene sequences were obtained.

Aphid life history traits

Aphids were reared on jalapeño pepper plants placed inside mesh and aluminum boxes (60 cm × 60 cm × 60 cm) under screenhouse conditions (average values of 24.9 °C ± 4.1 and 87.9 % r.h ± 9.2). For life history trait experiments, aphids were fed tabasco pepper leaflets kept fresh in plastic Petri dishes (9.0 cm × 1.6 cm) with agar (35 ml of an agar medium and 10 % water) and under controlled conditions (25 °C ± 0.5, 75 ± 1.75 % r.h., photoperiod L12:D12, and LS 5-Light Storm) in a climatic chamber (Humidity Panasonic Model MLR-351H-PA®.

Duration of the immature and adult stages

To establish the duration of aphid immature and adult stages, newborn nymphs were observed daily until they completed their development. The

presence of the exuvia marked the duration of the nymphal instar. Aphid development was divided into four stages: i) presence of immature stages, ii) presence of pre-reproductive adults, iii) presence of reproductive adults, and iv) presence of post-reproductive adults. The evaluated time lapse for all stages in every identified aphid species was recorded in days.

Development time, survival rate, and proportion of females

Adult females of each aphid species (n = 148 for *A. gossypii* and n = 150 for *M. persicae*) were placed individually in Petri dishes with agar on chili pepper leaflets. Nymphs were fed with new chili pepper leaves every three days and females were withdrawn as soon as they delivered their first nymph. Development time (days) was established from the first nymphal stage until the emerged female delivered the first descendant nymph (pre-reproductive period). Survival rate of immature individuals and proportion of females of each aphid species were recorded.

Aphid longevity and reproduction

Newly emerged adult females were moved to Petri dishes with agar on chili pepper leaflets. To determine longevity and fertility values, the number of nymphs produced by each female (n = 45 for *A. gossypii* and n = 49 for *M. persicae*) was registered every 24 hours until the female died.

Aphid demographic traits

Development time and survival of immature individuals were combined with experimental reproduction data to create life tables "$l_x - m_x$" and calculate aphid demographic traits. The following parameters were calculated for each species: net reproductive rate (R_0, is the number of daughters replacing an average female in the course of a generation), and generational time (T, describes the time between each generation). To calculate the intrinsic rate of population growth (r_m) per species, **Eq. 1** was used [23]:

$$\Sigma\ exp\ (-r_m x) l_x m_x = 1 \quad (1)$$

Where: x = age (days), l_x = female age-specific survival, and m_x = proportion of female offspring of a female at age x. Following Carey [23], the pivotal female age was used, i.e. $x + 0.5$ to calculate the r_m value.

Statistical analysis

Average values were accompanied with standard errors (± SE). The normality of data was checked using the Shapiro–Wilk test. Differences among species

concerning longevity, fertility, development time, and length of each development stage were compared via the Student's t-test using the Software R v3.3.4 ® [24]. The Chi square test was used to compare the number of aphids surviving to adulthood within aphid species.

Results

Taxonomic identification of chili pepper aphids

Two aphid species were collected in the chili pepper crops assessed in 29 commercial farms from 18 localities in ten municipalities of Colombia. The two species were *Aphis gossypii* Glover, 1877 and *Myzus persicae* (Sulzer, 1776). Out of the 29 locations sampled, aphids were found at 20 sites, with *A. gossypii* detected at 19 sites (65.5 %), *M. persicae* at 5 sites (17.2 %,) and both species at 4 sites (13.8 %). *Aphis gossypii* dwelled mostly in tabasco pepper (66.7 %), followed by cayenne pepper (14.3 %), jalapeño pepper (9.5 %), and habanero pepper (9.5 %). Likewise, the main host for *M. persicae* was tabasco pepper (80 %), followed by jalapeño pepper (20 %). The distribution of both aphid species in the geographic valley of the Cauca River (southwestern Colombia) in all chili pepper species is shown in **Fig. 1** and expanded in **Suppl. 1.**

Identification of aphids with DNA barcoding

COI gene sequences from 40 aphids, collected in jalapeño, habanero, tabasco, and cayenne chili pepper crops from different localities, were obtained. The N-J analysis on the COI sequences produced two distinct groups (**Fig. 2**). The genetic distance within every cluster was 0 %, revealing the existence of a unique haplotype in each group. Haplotypes were deposited into the GenBank under the unique accession codes MH203408 for *A. gossypii* and MH203409 for *M. persicae*.

The distance between clusters was 10 %, which matches interspecific differentiation. When comparing these haplotypes with those available in public databases, only matches with 100 % similarity and coverage were considered to identify sequences. Thus, sequences in clade A agreed with the species *A. gossypii*, whereas sequences in clade B belonged to the species *M. persicae* (Fig. 2). Aphids reared under laboratory conditions matched the GenBank sequences for *A. gossypii* and *M. persicae*, and corresponded to the morphological identification of each development stage of both species (**Fig. 3**). Additionally, the Barcoding technique established that yellow, yellow-light green, yellow-dark green, and black/black-green aphids observed in the field and in the laboratory are phenotypical variations of the species *A. gossypii*.

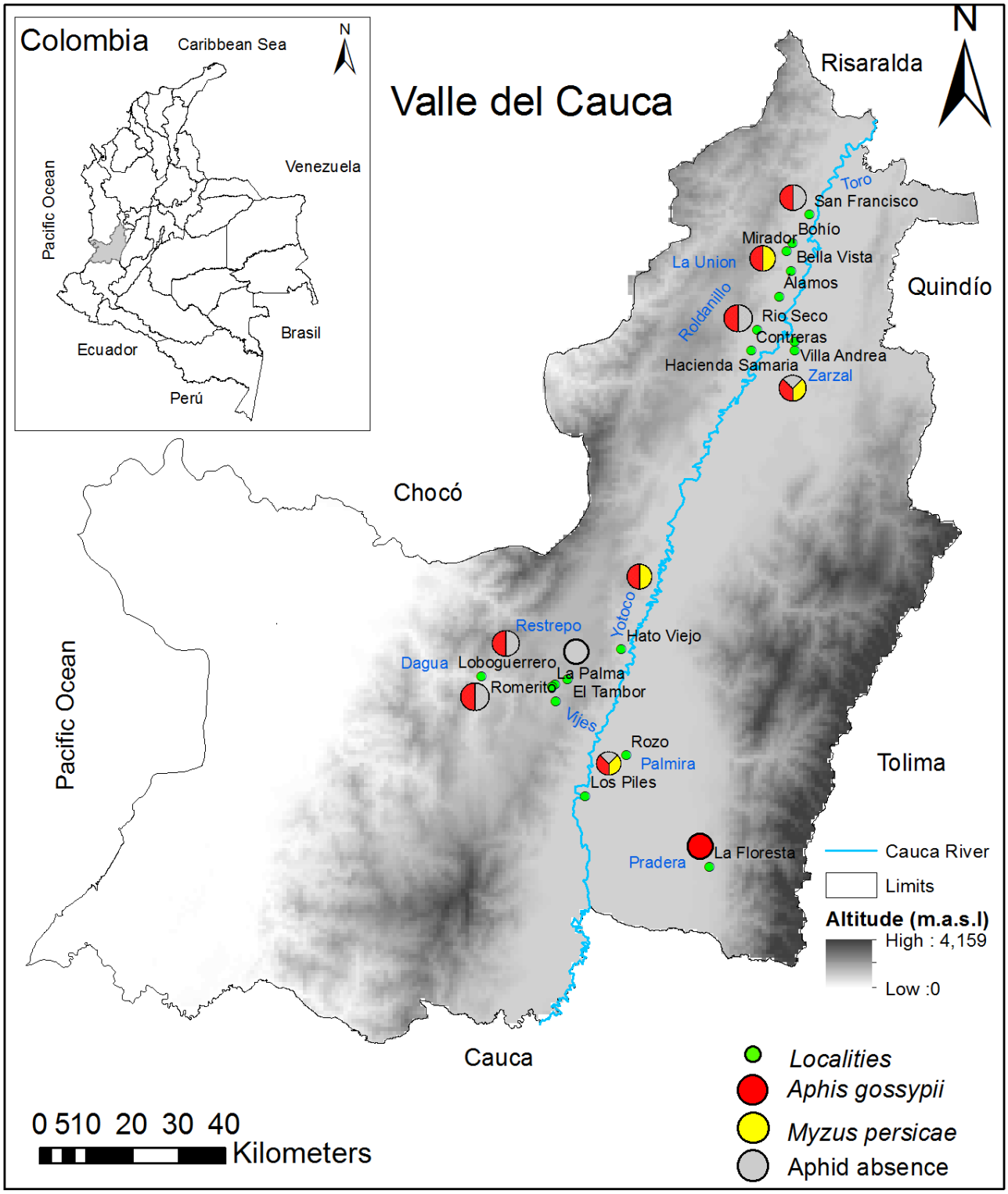

Figure 1. Distribution map of aphid species (presence – absence) in the surveyed areas. *Aphis gossypii* (red circle), *Myzus persicae* (yellow circle), and absence aphid (gray circle). Names of the municipalities are indicated in blue color and those of sampling locations in green color.

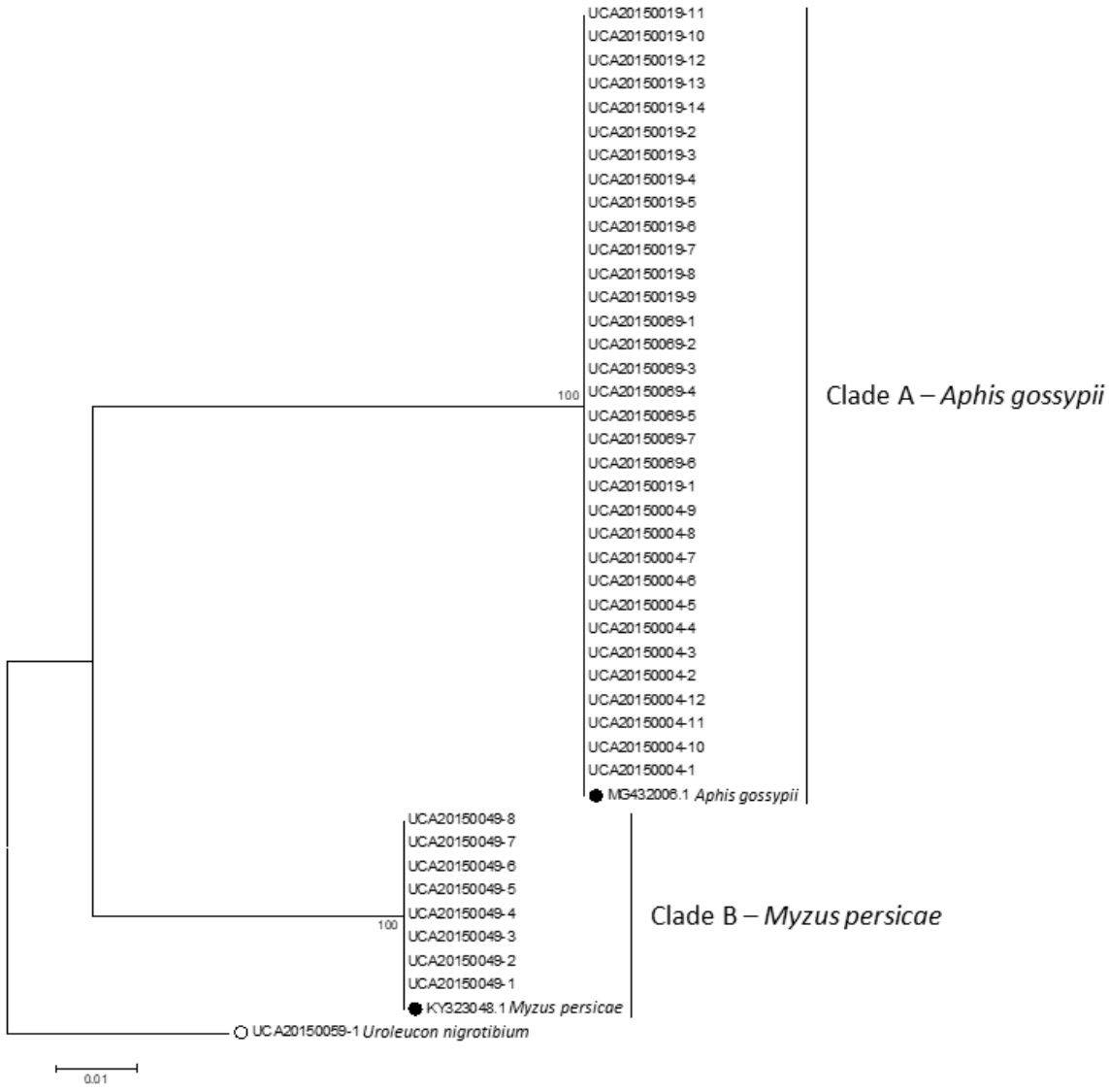

Figure 2. Sequences grouping analysis of Aphididae employing the N-J (1 000 bootstraps) method, under a K2P model. The Black circles indicate the sequences obtained from GenBank exhibiting 100 % identity with the Aphididae individuals sampled in *Capsicum* spp. The white circle indicates the external group used in the analysis.

Life history traits of *M. persicae* and *A. gossypii*

Polychromia was observed in *Aphis gossypii*, aphids of these species exhibited yellow, yellow-light green, yellow-dark green, black and black-green body colors during their development. *Myzus persicae* aphids showed all a light-yellow color during its development. Both *M. persicae* and *A. gossypii* went through four nymphal instars (Stage 1 – Stage 4) with an average length of 1.4 days per stage for *M. persicae* and of 1.1 for *A. gossypii* (**Table 1**).

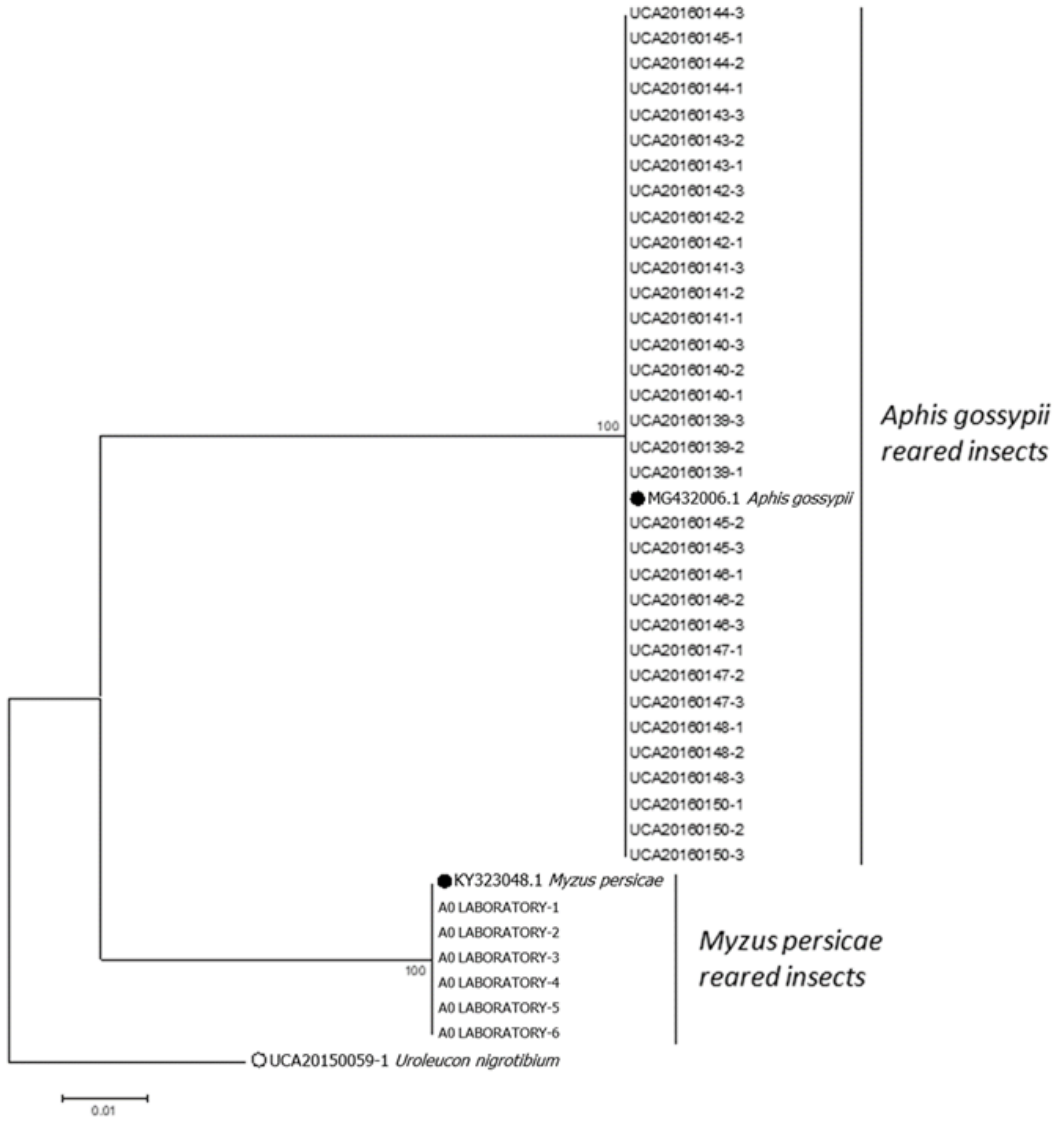

Figure 3. Grouping analysis employing the N-J (1 000 bootstrap) method, under a K2P model of aphid sequences raised in the laboratory. The black circles indicate the obtained GenBank exhibiting 100.

A difference regarding the duration of each of the nymphal instars was found between *A. gossypii* and *M. persicae* (Table 1): Stage 1 ($t = -16.09$, $d.f = 296$, $P < 0.001$), Stage 2 ($t = -5.42$, $d.f = 296$, $P < 0.001$), Stage 3 ($t = -11.04$, $d.f = 296$, $P < 0.001$) and Stage 4 ($t = -16.89$, $d.f = 296$, $P < 0.001$). All phases lasted longer in *M. persicae* than in *A. gossypii* (Table 1).

Only females were obtained in the adult stage, confirming reproduction by thelytokous parthenogenesis in both aphid species. The adult stage exhibited three reproductive phases. The first was the pre-reproductive phase, which

Table 1. Average development length (days ± SE) within the different nymphal stages of *Aphis gossypii* (n = 148) and *Myzus persicae* (n = 150) under controlled conditions (25 °C ± 0.5, 75 ± 1.75 % r.h., and photoperiod L12:D12, LS 5-Light Storm) in cayenne pepper (*Capsicum annuum*). Asterisks indicate significant statistical differences between species means (P < 0.001).

Species	Stage 1	Stage 2	Stage 3	Stage 4
M. persicae	1.50* ± 0.016	1.24* ± 0.019	1.40* ± 0.017	1.50* ± 0.019
A. gossypii	1.14 ± 0.002	1.09 ± 0.001	1.10 ± 0.001	1.10 ± 0.001
t	- 16.09	- 5.42	- 11.04	- 16.89
d.f	296	296	296	296
P	< 0.001	< 0.001	< 0.001	< 0.001

was significantly longer (t = -6.78, d.f = 92, P < 0.001) in *M. persicae* (0.90 days ± 0.016, n = 49) compared to *A. gossypii* (0.73 days ± 0.072, n = 45). The second was the reproductive phase, being also longer (t = -8.65, d.f = 92, P < 0.001) in *M. persicae* (16.98 days ± 0.037, n = 49) compared to *A. gossypii* (12.64 ± 0.320, n = 45). The post-reproductive phase; however, was longer (t = 12.02, d.f = 92, P < 0.001) in *A. gossypii* (7.95 days ± 0.072, n = 45) compared to *M. persicae* (1.32 ± 0.017, n = 49, **Table 2**). Although inter-specific, immature to post-reproductive stage, length differences were observed, these were not statistically significant (t = -0.28, d.f = 92, P = 0.774; *M. persicae*: 24.84 ± 0.063, n = 49 and *A. gossypii*: 25.75 days ± 1.710, n = 45; Table 2). Concerning reproduction, *A. gossypii* aphids devoted half their lifespan to reproduction, and *M. persicae* devoted slightly more time to the same activity.

The length of the nymphal period was significantly longer (t = -28.41, d.f = 296, P < 0.001) in *M. persicae* (5.64 ± 0.071, n = 150) compared to *A. gossypii* (4.43 ± 0.014, n = 148, Table 2). Survival from N1 to adult was significantly higher (X^2 = 8.416; df = 1; P = 0.004) for *M. persicae* (100 %, n = 49) compared to *A. gossypii* (93.2 %, n = 45). Only daughters were obtained in both species.

Table 2. Average duration of the nymphal stage of *Aphis gossypii* (n = 148) and *Myzus persicae* (n = 150), the adult stage (pre-reproductive, reproductive and post-reproductive) and the nymph-adult period (days ± SE) of *Aphis gossypii* (n = 45) and *Myzus persicae* (n = 49) under controlled conditions (25 °C ± 0.5, 75 ± 1.75 % r.h., photoperiod L12:D12, and LS 5-Light Storm) in cayenne pepper (*Capsicum annuum*). Asterisks indicate significant statistical differences between species means (P < 0.001).

Species	Nymph-Adult	Pre-reproductive	Reproductive	Post-reproductive	Nymph Post-reproductive adult
M. persicae	5.64* ± 0.071	0.90* ± 0.016	16.98* ± 0.037	1.32* ± 0.017	24.84* ± 0.063
A. gossypii	4.43 ± 0.014	0.73 ± 0.072	12.64 ± 0.320	7.95 ± 0.072	25.75 ± 1.710
t	- 28.41	- 6.78	- 8.65	12.02	- 0.28
d.f	296	92	92	92	92
P	< 0.001	< 0.001	< 0.001	< 0.001	0.774

The average longevity in female adults was similar between *A. gossypii* (25.9 ± 0.49 days) and *M. persicae* (25.0 ± 0.42 days; **Table 3**). Daily average fertility was also similar in both species, i.e. 3.9 ± 0.60 nymphs/female for *A. gossypii* and 3.4 ± 0.41 nymphs/female for *M. persicae*. In addition, the overall average fertility was similar (t = -1.89, df = 92, P = 0.060) between *M. persicae* (71.28 ± 1.876 nymphs) and *A. gossypii* (65.55 ± 2.310 nymphs; Table 3).

Fig. 4A shows survival (l_x) and fertility (m_x) curves for *M. persicae*. These females started to reproduce when they were two days old and delivered an average of four nymphs per day. They reached maximum fertility at six days

Table 3. Average longevity (days ± SE) and fertility (nymphs/female ± SE) of *Aphis gossypii* (n = 45) and *Myzus persicae* (n = 49) in cayenne pepper (*Capsicum annuum*) under controlled conditions (25 °C ± 0.5, 75 ± 1.75 % r.h., photoperiod L12:D12, and LS 5-Light Storm).

Parameter	Aphids species		t	d.f	p
	A. gossypii	*M. persicae*			
Average longevity ± SE (days)	25.9 ± 0.49	25.0 ± 0.42	1.25	88	0.209
Range	20.1 - 33.1	19.7 - 30.7			
Average fertility ± SE (daughters/female)	65.55 ± 2.31	71.28 ± 1.87	- 1.91	98	0.048*
Range	30 - 90	44 - 99			
Daily average fertility ± SE (daughters/female)	3.9 ± 0.60	3.4 ± 0.40	0.62	37	0.534
Range	0.1 - 6.8	0.3 - 6.1			

old (six nymphs on average per day), and when they were 12 days old, fertility decreased steadily. No female died during the first 14 days assessed. In fig. 4B, survival (l_x) and fertility (m_x) curves for *A. gossypii* are displayed. Females started to reproduce when they were one-day old and delivered an average of one nymph per day, reaching a maximum fertility (7 nymphs on average per day) when they were five days old. After 11 days old, fertility decreased rapidly. No female died during the first 11 days of evaluation.

Demographic traits of *M. persicae* and *A. gossypii*

The intrinsic rates of population growth (r_m) for *M. persicae* and *A. gossypii* were 0.39 and 0.43, respectively (see Eq. 1). Generational time (T) was higher for *M. persicae* (13.8 days) compared to *A. gossypii* (11.7 days) and the net reproductive rate (R_0) was 65.5 for *A. gossypii* and higher for *M. persicae*, with 72.8.

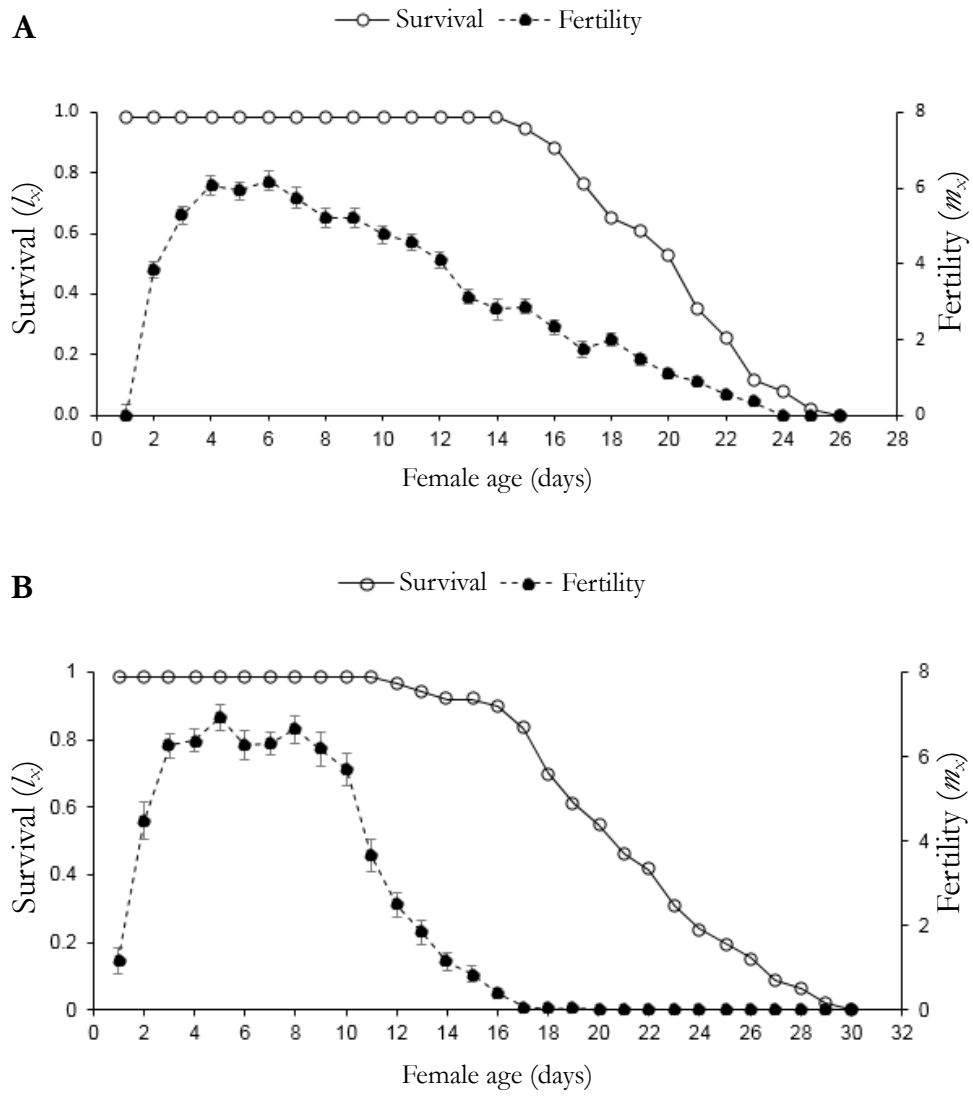

Figure 4. Survival (l_x) is expressed as the number of live females and fertility (m_x) is expressed as the number of nymphs per female; (A) *Myzus persicae* (n = 49) and (B) *Aphis gossypii* (n = 45) on *Capsicum annuum* plants (cayenne pepper) under controlled conditions (25 °C ± 0.5, 75 ± 1.75 % r.h., and photoperiod L12:D12, LS 5-Light Storm). Error bars indicate ± standard error of the mean.

Discussion

Globally, sixteen aphid species have been reported in chili pepper (*Capsicum* spp.) crops [2]. Our research indicated that the aphid pest community associated with chili pepper crops in southwestern Colombia is much less diverse than expected [15]. The only aphid species found were

M. persicae and *A. gossypii*, the latter being the one with the highest incidence. Both species have previously been reported in chili pepper crops [25, 26]. Specifically, in the tropics, a low aphid species diversity is a common situation due to the short period in which aphids can survive without food. Three related factors contribute to this situation, (i) aphids must meet the high food demands of the embryos developing within them, (ii) they exhibit a high degree of host specificity, and (iii) they are not efficient in locating host plants [27]. Furthermore, our results show that the lack of genetic variation within *A. gossypii* and *M. persicae* could be a consequence of the observed situation; females were genetically identical since they reproduced exclusively by parthenogenesis.

The DNA barcoding technique confirmed and supported the morphological identification of *A. gossypii* and *M. persicae* [4, 10]. Barcoding was useful to overcome species diagnostic difficulties in aphids. These difficulties are due to loss of useful taxonomical characters, phenotypic plasticity related to host plant interactions, stress, morphological particularities within each development stage, as well as polychromy [11]. In fact, most of these were observed specifically in *A. gossypii*.

Climate variables, especially temperature, influence the demographic traits of aphids [28]. The highest incidence of *A. gossypii*, and, concomitantly, the lowest incidence of *M. persicae* in the assessed chili pepper crops (18.6–30.1 °C range) can be partially explained by the adaptation capacity of each species to tropical temperature. *M. persicae* is greatly affected by high temperatures, with an optimal development between 15–20 °C [29], thus being mostly found in temperate regions [30]. On the contrary, *A. gossypii*, has its best performance between 26–30 °C [31] and prefers tropical zones [32]. Nevertheless, the average immature development time (from the first nymphal stage up to the post-reproductive adult) was 25.7 days for *A. gossypi* and 24.8 days for *M. persicae*. These values were similar in our study, since temperature [33] and host plant conditions [34] affect the length of the development of aphids. Both species showed four nymphal stages, as found by Dixon *et al*. [27], lasting between 1.1–1.5 days, on average. This range matches what has previously been reported in chili pepper crop aphids [35].

The development time from nymph 1 (Stage 1) to adult was short for both species (<6 days). This makes it possible to obtain females rapidly, which will start to reproduce the day after emerging. These features, as well as their reproduction via obliged thelytoky parthenogenesis, are common in tropical regions [12], and allow both species to develop larger populations in a short amount of time. Our results show that their descendants are clones, with adaptive characteristics for local environmental conditions [36].

Both species delivered around three or four nymphs per day although the length of the reproductive period was significantly higher for *M. persicae*, than for *A. gossypii*. This finding clashes with the idea of a less adapted *M. persicae* to hot climates; namely this species showing higher fertility and longevity at temperatures below 15 °C [37]. Nevertheless, the trait values we observed seem to reflect the adaptation of the aphid to chili pepper crops. For instance, a maximum overall average fertility of 62.7 individuals at 25 ± 1 °C [25] has been reported in bell pepper (*C. annuum*) aphids, which is a lower value than what we observed in our work.

The post-reproductive period was shorter for *M. persicae* (<2 days), indicating that females of this species die quickly after they reproduce [38], whereas in *A. gossypii* we observed a longer post-reproductive period. *M. persicae* compensates its shorter survival time with a broader reproduction period that could be interpreted as an adaptive advantage in this species. These biological differences can influence virus transmission dynamics in the assessed chili pepper crops [39], given that *A. gossypii* stays and feeds longer in the crop, thus having more chance to spreading the virus.

Population parameters needed to create life tables for aphids are highly influenced by the host plant [34, 14] and by the environmental temperature [31]. In fact, the *Capsicum* r_m values found in our study are in the range reported by other authors. In *C. frutescens* and *C. annuum*, the r_m values of 0.27 and 0.48 for *A. gossypii* were reported by Singh and Singh [40] and Satar *et al*. [41], respectively. For *M. persicae* in *C. annuum*, r_m values of 0.31 [29], 0.33 [25] and 0.41[41] were reported.

According to our results, net reproductive rate (R_o) and generational time (T) were superior in *M. persicae* (72.8 and 13.8, respectively) than in *A. gossypii* (65.5 and 11.7, respectively). The R_o value found in *A. gossypii* is superior to the one reported in cotton crops, i.e. 21.7 and 24.8 at a temperature of 27.5 ± 1 °C [34] and 40 at a temperature of 23 °C [42]. This depicts, once again, the adaptative capacity of *A. gossypii* to chili pepper crops.

Biological and demographic features show the adaptation of both aphid species to *Capsicum* spp., although *A. gossypii* is more frequent and abundant. Therefore, future studies are needed to establish if this asymmetry is a product of direct competitive interactions in these crops. Precisely, Denno *et al*. [43] mention the following facts as competition triggers between the two species: both are sap feeders, live in aggregates, and inhabit managed environments (i.e. agroecosystems). On the other hand, top-down cascades represented by the diversity of the natural enemies of aphids (for instance, Coccinellid beetles)

[44] found in chili pepper crops and their companion plants (unpublished data) could be shaping the incidence of the aphid species [45]. In addition to these trophic cascades, the insecticides sprayed in the crops sampled could have affected the incidence of aphids, either decreasing their presence [46] or favoring it through the elimination of their natural enemies [47].

Although the presence of aphids causes demonstrable yield losses in several crops [48], for chili pepper crops, the greatest concern is the economic loss caused by the viruses transmitted by both aphid species. These viruses, transmitted through the stylet when feeding, appear in a non-persistent manner (unpublished data). The higher population growth of *A. gossypii*, a consequence of better adaptation to tropical climates [32] than *M. persicae* [37], could be reflected in a larger virus spread. However, our demographic results for *M. persicae* suggest that this species could be adapting to warm climates.

Conclusions

A. gossypii and *M. persicae* are currently the only aphid species present in *Capsicum* spp. crops in southwestern Colombia. *A. gossypii* has a higher incidence and shows sharp polychromy during its development.

Both aphid species reproduce via thelytoky parthenogenesis combined with a short immature development phase (less than 6 days), which allows them to produce large populations in a short period. Females live between 25-26 days, showing an average daily fertility of 3-4 daughters, although *M. persicae* shows a longer reproductive period.

The intrinsic rate of natural growth r_m was lower in *M. persicae* (0.39) compared to *A. gossypii* (0.43). Results suggest that *A. gossypii* and *M. persicae* are adapted to chili pepper crops and their high fertility, high survival, and short development time favor the function of both species on virus dispersion. Their role as virus vectors must be clarified for both species in *Capsicum* crops.

Acknowledgements

This work was funded by grants of Universidad Nacional de Colombia –Palmira campus– (HERMES 35892, HERMES 36866, HERMES 31256 and HERMES 39271) and Fondo CTeI-Sistema General de Regalías (BPIN 2013000100007).

We thank Hugo Restrepo & Cia. S.A. for aiding during the collection of research samples in the chili pepper crops. We thank Francisco Serna and Ronald Simbaqueba at the Agronomy Museum of Universidad Nacional de Colombia UNAB for aphid species confirmation. We acknowledge especially the two anonymous reviewers for their valuable comments to our manuscript.

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Identificación e historia de vida de áfidos asociados con cultivos de chile en el suroeste colombiano

Resumen: Las enfermedades virales transmitidas por áfidos son uno de los problemas más limitantes en los cultivos de chile. La comprensión de las características demográficas de estos áfidos puede contribuir al diseño de mejores estrategias de control en el chile. Las especies de áfidos que se encuentran en cultivos de chile en el suroccidente colombiano fueron identificadas como *Aphis gossypii* Glover y *Myzus persicae* (Sulzer). Se investigó un conjunto de parámetros de la historia de vida de ambas especies a 25 °C ± 0.5, 75 ± 1.75 % r.h., L12:D12, y LS 5-Light Storm en cultivos de chile. Ambas poblaciones de áfidos estaban compuestas únicamente de hembras partenogenéticas, y mostraban un tiempo de desarrollo promedio similar –del primer estadio ninfal al adulto post-reproductivo–, así como de longevidad de las hembras y de valores promedio diarios de fertilidad. La longitud del periodo reproductivo fue mayor para *M. persicae*. *A. gossypii* alcanzó su estado adulto significativamente más rápido que *M. persicae*. La tasa intrínseca de crecimiento poblacional (r_m) fue menor para *M. persicae* (0.39) comparada con *A. gossypii* (0.43). Los resultados mostraron el potencial de crecimiento rápido de ambas especies, lo cual potencia su papel como vectores de virus. La información adquirida es esencial para desarrollar iniciativas de manejo de pestes para estas dos especies de áfidos.

Palabras clave: *Aphis gossypii*, código de barras, *Capsicum*, *Myzus persicae*, valores r_m.

Identificação e história de vida de pulgões associados a plantações de pimenta no sudoeste da Colômbia

Resumo: As doenças virais transmitidas por pulgões são um dos problemas mais limitantes nos cultivos de pimenta. O entendimento das características demográficas de estes pulgões pode contribuir ao desenho de melhores estratégias de controle em pimenta. As espécies de pulgões que se encontram em cultivos de pimenta no sudoeste da Colômbia foram identificadas como *Aphis gossypii* Glover e *Myzus persicae* (Sulzer). Foi investigado um conjunto de parâmetros da historia de vida de ambas espécies a 25 °C ± 0,5, 75 ± 1,75 % H.R, L12:D12, e LS 5-Light Storm em culturas de pimenta. Ambas populações de pulgões estavam constituídos unicamente de fêmeas partenogenéticas e mostravam um tempo médio de desenvolvimento similar –desde o primeiro estágio ninfal até o adulto pós-reprodutivo–, longevidade da fêmea e valores diários médios de fertilidade. A duração do período reprodutivo foi maior para *M. persicae*. *A. gossypii* alcançou seu estado adulto significativamente mais rápido que *M. persicae*. A taxa intrínseca do crescimento populacional (r_m) foi menor para *M. persicae* (0,39) comparada com *A. gossypii* (0,43). Os resultados mostraram o potencial de rápido crescimento de ambas espécies, o qual pode ampliar seu papel como vetores virais. A informação adquirida é essencial para desenvolver iniciativas de controle de pestes para estas duas espécies de pulgões.

Palavras-chave: *Aphis gossypii*, código de barras, *Capsicum*, *Myzus persicae*, valores r_m.

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