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Overwintering of the Argentine strain of *Neoseiulus californicus* (Acari: Phytoseiidae)

María Fernanda Gugole Ottaviano[1,3] · Mariángeles Alonso[2] · Claudia Cédola[2] · Mariana Pascua[2] · Martha Roggiero[2] · Nancy Greco[2,3]

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Abstract
Overwintering and diapause are variable among mite species and strains. The aims of this study were to determine whether certain crops constitute overwintering sites for the Argentine strain of the predator *Neoseiulus californicus* and whether females underwent reproductive diapause in winter. *Neoseiulus californicus* was recorded monthly on the vegetables tomato, sweet pepper, eggplant, and artichoke, and on strawberry, among other crops in Buenos Aires province, Argentina. This mite was found at a lower percentage of crops in the winter than in the other seasons. Since the predator was quite frequent on artichoke, this crop could constitute a refuge during adverse environmental conditions. The mite's frequency on several crops in other seasons and potential association with a strawberry pest is discussed. In the laboratory, individuals exposed to winter conditions throughout the life cycle exhibited a long pre-oviposition period and low oviposition rate, but did not diapause. After being kept under winter conditions from larva to adult, when individuals were transferred to the optimal spring temperatures and lighting, the pre-oviposition period was shorter and the fecundity higher than under winter conditions. When individuals remained under spring conditions from larva to adult and were then transferred to the winter parameters during the first 15 days of adulthood, the pre-oviposition period was long and the oviposition rate low. Once the optimal conditions were restored, the daily fecundity became similar to that of the individuals remaining under optimal conditions throughout the life cycle. Fecundity of *N. californicus* decreased significantly under winter conditions but reproductive diapause was not observed.

Keywords *Neoseiulus californicus* · Overwintering · Diapause · Horticultural crops

✉ Nancy Greco
ngreco@cepave.edu.ar

1 Departamento de Evaluación Sensorial de Alimentos (DESA–ISETA), 9 de Julio, Buenos Aires, Argentina

2 Centro de Estudios Parasitológicos y de Vectores (CEPAVE), Facultad de Ciencias Naturales y Museo, UNLP, CONICET, Boulevard 120 s/no. 60 y 64, CP1900 La Plata, Argentina

3 Comisión de Investigaciones Científicas de la Provincia de Buenos Aires, La Plata, Argentina

Introduction

The effectiveness of phytoseiids in biological control depends on various attributes including their ability to survive food shortages and adverse climatic conditions (Hart et al. 2002). Overwintering sites are often sought out by diapausing phytoseiid females within different plant systems. Chant (1959) suggested that overwintering females do not relocate to the ground upon leaf fall in autumn but rather move under bark or to sites such as splintered twigs and crevices. Moreover, when phytoseiid females were collected from peach orchards, the overwintering sites varied among species, ranging from orchard weeds to many locations on shrubs and trees (Putman 1959; Jung and Croft 2000). Phytoseiids inhabiting annual herbaceous plants move in the fall to evergreens such as *Ranunculus* spp. and *Urtica dioica*, where those mites become concentrated for spending the winter (Chant 1959).

Not all species, strains, or populations of phytoseiids are capable of entering diapause, and certain predatory mites can overwinter successfully without doing so (Morewood 1993). In temperate and cooler regions, the females of phytoseiid mites generally undergo reproductive diapause that has been assessed through the absence of egg formation or the shift to a prolonged preoviposition period at low temperatures, during short photoperiods, or under conditions of low food quality or quantity (van Houten 1989; van Houten and Veerman 1990; Veerman 1992). In most phytoseiid species, the sensitivity to diapause-inducing stimuli extends over only several immature stages, whereas other species remain diapause-sensitive, at least to shortened photoperiods, during the adult stage (Overmeer 1985; Morewood 1993; Kishimoto and Takafuji 1994). In contrast, species from subtropical regions often maintain a continuous development that is uninterrupted by dormancy (Hart et al. 2002).

Within the context of biological control, diapause is desirable as this physiological state favors the persistence of predators in the agroecosystem (Gotoh et al. 2005) and, along with enabling an increased survival at low temperatures, could also facilitate synchronization with the seasonal phenology of the predator's main prey (McMurtry and Flaherty 1977; Mori and Saito 1979).

The predatory mite *Neoseiulus californicus* (McGregor)—found on various crops in Europe, North and South America, and Asia—has been reported to be highly effective in controlling the two-spotted spider mite *Tetranychus urticae* Koch (Acari: Tetranychidae) in several crops (Fraulo and Liburd 2007; Greco et al. 2011; van Lenteren 2012). This predator can adapt to variations in the prey populations, thus providing stable pest suppression over time (Castagnoli and Simoni 2003; Escudero and Ferragut 2005; Greco et al. 2005, 2011).

Neoseiulus californicus may overwinter in locations other than living plants, such as under litter and in soil (Veerman 1992; Nyrop et al. 1994). Kawashima and Jung (2011) found that the winter survival of this mite was higher under fallen leaves than on the bare ground, suggesting that sheltered ground habitats may likewise provide effective protection from the adverse effects of the low winter temperatures. Raworth et al. (1994) also suggested that *N. californicus* climbed apple trees from the ground during the spring in the south of France. Kawashima and Jung (2010) observed that *N. californicus* overwintered on herbaceous weeds on the ground, rather than on mandarin trees or woody plants surrounding the orchards. With respect to the herbaceous plant species, higher densities of *N. californicus* were found on those with rosette-type leaves, the morphology of which constituted a sheltering structure, i.e., between the broad leaves, between the leaves and the ground, as well as inside the dense leafstalks. These structures may have protective features similar to those of the aforementioned sheltered ground habitats so as to reduce the mite's winter mortality. Gugole Ottaviano et al. (2015) registered *N. californicus* in autumn and winter on wild vegetation, surrounding horticultural crops—locations that could provide a temporary habitat with pollen as alternative food.

The indigenous Argentine strain of *N. californicus* is an effective control agent for *T. urticae* in strawberry plants, appearing early in the crop (Greco et al. 1999, 2005, 2011). Greco et al. (2006) found that, after surviving a short period of food deprivation, the females of the Argentine strain of *N. californicus* were capable of reproducing when two-spotted spider mites became available as food. In that instance, the adult survival after 96 h of food deprivation reached 62.5% with reproduction beginning only after the prey were reintroduced, by implying that stored energy in general is preferentially allocated for survival over reproduction. Diapause has been documented in other *N. californicus* strains, though the state was found to vary among them (Castagnoli and Simoni 1999; Jolly 2001; Hart et al. 2002). Diapause, however, has not yet been investigated in the Argentine strain of the Buenos Aires province.

Conservation of natural enemies through habitat manipulation requires a compromise in the selection of plants that on the one side provide food resources, shelter and oviposition sites, whereas on the other side are not host of other herbivores that may attack the crop (Escudero and Ferragut 1999). Our particular Argentine strain of *N. californicus* has been found on various weeds throughout the year, especially in autumn and winter. The common nettle *Urtica urens*, the henbit nettle *Lamium amplexicaule*, and the milk thistle *Sonchus oleraceous* could also promote the persistence of *N. californicus* by hosting *T. urticae* and thrips and/or by providing pollen as an alternative source of nutrition when the prey density in the strawberry is low (Gugole Ottaviano et al. 2015). The proximity of wild plants and other crops that offer resources for *N. californicus* overwintering could favor its persistence in the agroecosystem.

The objective of this study was to investigate whether certain crops could constitute hibernation sites for this native strain of *N. californicus* and whether females of this species have reproductive diapause during the hibernation conditions.

Materials and methods

Field sampling

The field sampling was performed in four farms (1–3 km in between) in Los Hornos, a suburb of the city of La Plata in the Buenos Aires province, Argentina (38°52′S, 57°59′W). These horticultural farms were representative of those of the region, in which several crops—tomato, sweet pepper, eggplant, artichoke, leafy vegetables, and strawberry among others—are cultivated throughout the year under open-field or greenhouse conditions.

Neoseiulus californicus, *T. urticae*, and other arthropods commonly present on strawberry plants, such as aphids, thrips, white flies, and the mite *Tydeus kochi* Oudemans, were recorded monthly from 30 sampling units (i.e., leaves) randomly selected from each crop from April 2005 through March 2009. The frequency (%) of a particular arthropod in a crop per season of the year was calculated as: 100 × (number of leaves with the arthropod)/(total number of leaves sampled in a season).

The associations between *N. californicus*, crops, and the other mites and insects present during each season were assessed by a correspondence analysis PCoA (Pielou 1984). Only the crops in which *N. californicus* was present during each season were included in the analysis. The distances between the observed and expected frequencies were analyzed by the χ^2 test according to the null hypothesis of independence.

Laboratory assays

Neoseiulus californicus and *T. urticae* colonies were started from individuals collected from strawberry crops in La Plata, Argentina, and maintained separately under controlled conditions of 25 ± 2 °C, 60–70% relative humidity and L14:D10 photoperiod, for > 10 generations. Colonies were kept on completely expanded trifoliate strawberry leaves, with the petioles placed in water-filled test tubes to keep the leaves turgid, inside a plastic box (500 ml) covered with transparent film to prevent the individuals from escaping. Because of the morphological similarity of *N. californicus* to other species, the phytoseiids used to start the colony were identified as *N. californicus* on inspection under a binocular microscope according to Guanilo et al. (2008). The individuals selected were supplied with eggs, nymphs, and adults of *T. urticae* as food every 2 days using a fine sable-hair brush.

To obtain a cohort of *N. californicus* to start the assays, for each treatment 15 reproductive *N. californicus* females were placed with prey on a strawberry leaf at the same breeding unit, temperature, relative humidity and photoperiod aforementioned. After 2 days the females were removed and the eggs laid (group of 45 eggs) were incubated until hatching.

The treatments were (n = 10–16): (T1) individuals maintained under winter conditions (10 °C and L10:D14) from the larval stage onward; (T2) individuals kept under winter conditions from the larval to the adult stages, then placed under spring conditions (25 °C and L14:D10) throughout adulthood; (T3) individuals maintained under spring conditions from the larval to the adult stages and then shifted to winter conditions during the first 15 days of adulthood; and (T4, control) individuals held under spring conditions throughout the entire life cycle.

In all treatments (T1–T4), individuals reaching adulthood were continuously observed to record their mating. Once mating ended, the recently copulated females were placed individually on a strawberry leaf disk (1.8 cm diameter) with the abaxial side up placed on an agar disc of the same diameter and of 2 mm thick in a 2.5-cm-diameter Petri dish. The discs were surrounded with water to prevent the individuals from escaping and to keep moisture within the experimental unit. Food (a mixture of all stages of *T. urticae*) was provided ad libitum. The strawberry leaf disks and food were replaced when necessary. Age-specific survival (l_x) and age-specific fecundity (m_x) were calculated from the number of females surviving and the number of eggs laid, recorded daily.

Longevity, pre-oviposition period, oviposition period, number of eggs/female/day and total fecundity (number of eggs/female) were evaluated by one-way ANOVA and means were separated by the Tukey test. The data of the variables pre-oviposition period and reductive periods were square-root transformed. In all instances where the assumptions of normality and homoscedasticity required by the ANOVA were not met, the Kruskal–Wallis test was performed. Females that disappeared or drowned during the experiment were excluded from the analysis.

Eggs laid by T1 females were kept under winter conditions and eggs laid by T2–T4 females were kept under spring conditions. The proportion of hatched eggs and the survival of individuals that completed development were recorded. Differences between treatments (T1, T2, T3) and the control (T4) were analyzed by the normal-deviate Z test (Zar 1996).

Results

Field sampling

A similar crop richness of 19–21 species was registered in all the seasons (Fig. 1). *Neoseiulus californicus* was found in 52, 50, and 58% of the crops present in autumn, spring, and summer, respectively, whereas in winter the species was recorded in only 26%. The main prey, *T. urticae*, displayed a similar pattern, but was recorded in certain other crops at 71, 60, 79, and 37% of those present in autumn, spring, summer, and winter, respectively. *Neoseiulus californicus* was more frequent in cucumber, raspberry, and strawberry, and the species was frequent in artichoke particulary in winter (Table 1). The presence of *N. californicus* was associated with the occurrence of the prey in almost all these crops, though not in artichoke in winter.

Correspondence analysis between the frequency of *N. californicus*, crops, and other mites and insects present in autumn indicated that axis 1 accounted for 48.5% and axis 2 for 27.2% (cumulative inertia = 75.7%) of data variability (Fig. 2a). *Neoseiulus californicus* was associated with cucumber crops, whereas *T. urticae*—the predator's main prey—was associated with raspberry, corn, and cherry tomato crops. Aphids were associated with artichoke, chard, and celery crops, and white flies with strawberry, radicchio, and zucchini. In contrast, the mite *T. kochi* was associated with strawberry crops planted during the previous year (indicated as abandoned strawberries). In the winter (Fig. 2b) (axis 1: 56.9% and axis 2: 23.7%; cumulative inertia = 80.6%), *N. californicus* displayed a degree of association with artichoke, whereas the presence of *T. urticae*, together with white flies and *T. kochi*, was correlated with strawberry under

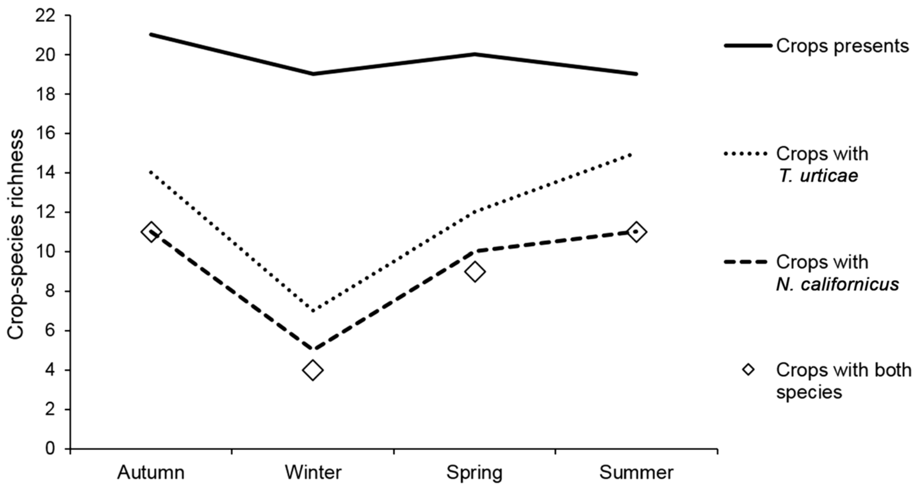

Fig. 1 The total number of crops in the farms of the horticultural belt of La Plata, Argentina (solid line) sampled during different seasons of the year and the number of crops with *Neoseiulus californicus* (dashed line), *Tetranychus urticae* (dotted line), or both species (diamonds) on the plants

Table 1 Frequency (%) of *Neoseiulus californicus* (Nc) and *Tetranychus urticae* (Tu) ([number of leaves with either species/total number of leaves taken at each season] × 100%), in crops from farms in the horticultural belt of La Plata, Argentina, during various seasons

Crop	Autumm		Winter		Spring		Summer	
	Nc	Tu	Nc	Tu	Nc	Tu	Nc	Tu
Artichoke	6	8	27	0	12.04	0.14	9.42	2.24
Lettuce	0	4	1	3	9.41	10	0	1.66
Radicchio	1	3	0	0	–	–	–	–
Celery	1	4	0	1	6.19	10.95	0	0
Parsley	0	0	0	0	0	0	–	–
Broccoli	0	0	0	0	0	0	–	–
Cauliflower	0	5	0	0	0	0	3.33	10
Cabbage	0	0	0	0	0	0	0	0
Brussels sprout	–	–	0	0	0	0	–	–
Cucumber	14	20	–	–	53.33	100	60	90
Zucchini	1	14	–	–	1.67	3.33	3.44	16.19
Bean	0	3	0	0	0.56	4.44	6.67	46.67
Green onion	0	0	0	0	0	0	0	0
Leek	–	–	0	0	4.44	0	–	–
Corn	4	33	–	–	0	0.97	0	9.67
Chard	2	1	0	1	0	0.83	8.15	12.59
Spinach	–	–	0	11	–	–	–	–
Beet	–	–	0	0	1.11	1.11	0	0
Raspberry	12	49	2	4	2.94	2.21	11.33	23.64
Strawberry (productive)	6	43	34	84	14.90	40.39	3.41	3.48
Strawberry (abandoned)	15	13	5	22	–	–	6.67	3.33
Eggplant	0	0	–	–	–	–	10.42	17.92
Sweet pepper	0	1	0	0	0	2	0	3.33
Cherry tomato	1	17	–	–	–	–	6.67	3.33
Tomato	0	0	–	–	0	0	0	4.76

– Crop was absent

current cultivation, strawberry planted the previous year, and raspberry. The aphids and thrips were associated with artichokes and lettuce, respectively. In the spring (Fig. 2c) (axis 1: 50.2% and axis 2: 23.7%; cumulative inertia = 73.9%), *N. californicus* was registered on crops of celery, raspberry, cucumber, strawberry, and lettuce along with *T. urticae*. By contrast, aphids were more closely correlated with beet, thrips with bean and leek, and white flies with zucchini and leek. *Tydeus kochi*, like *N. californicus*, was furthermore associated with artichoke. In the summer (Fig. 2d) (axis 1: 39.0% and axis 2: 30.8%; cumulative inertia = 69.8%), *N. californicus*, together with *T. urticae*, was found mainly on chard, cucumber and raspberry, whereas aphids were associated with cauliflower and artichoke, white flies with cherry tomato, *T. kochi* with abandoned strawberry, and thrips with eggplant, chard, bean, and zucchini.

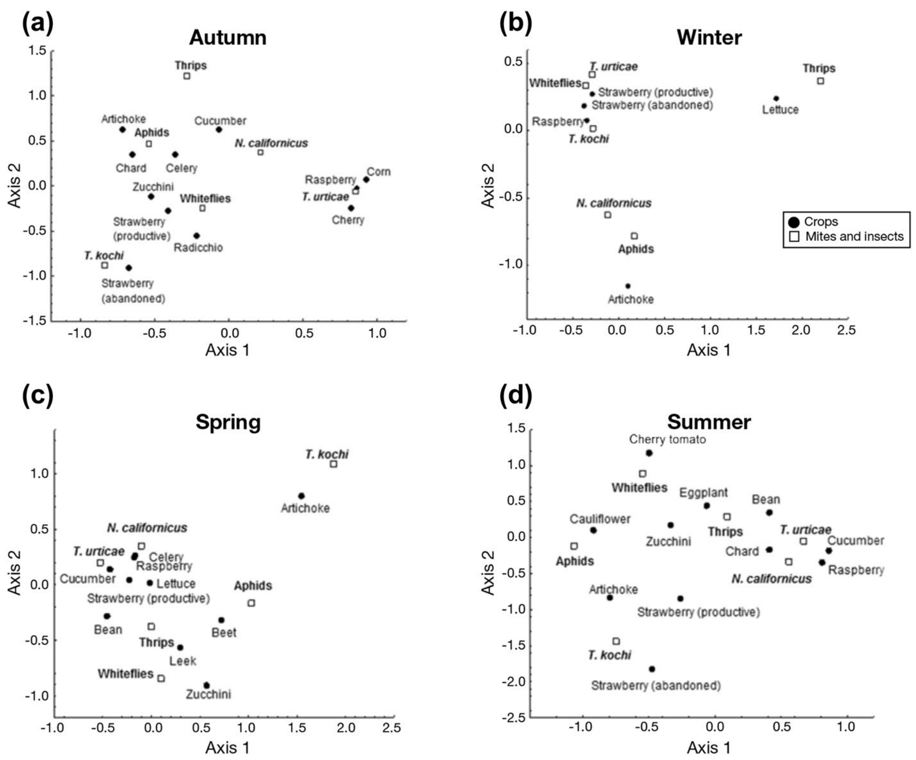

Fig. 2 Correspondence analysis of associations between the frequency of *Neoseiulus californicus*, the vegetable crops, and the other mites and insects present during autumn (**a**), winter (**b**), spring (**c**), and summer (**d**) in horticultural farms in La Plata, Argentina. In the figure, the circles indicate the crops surveyed, and the squares denote the presence of mites and insects associated with those crops

Laboratory assays

The *N. californicus* adult-female-survival curves were very different under different conditions of photoperiod and temperature (Fig. 3a–d). Survival was higher when individuals went through their entire life cycle under winter conditions—with 50% surviving until day 83 (T1; Fig. 3a)—than when the females were kept under winter conditions either from only the larval to the adult stages (T2; Fig. 3b) or during only the first 15 days of adulthood (T3; Fig. 3c), with the rest of the life cycle experiencing spring conditions. In either of those latter treatments (T2 and T3), 50% of the individuals survived until day 15 (Fig. 3b, c). The survival of individuals held under spring conditions throughout the entire life cycle (T4) was higher than survival in treatments T2 and T3 (50% surviving until day 39). The mean longevity of *N. californicus* females was, accordingly, different among the various treatments ($F_{3,29}=34.05$, $P<0.01$) and significantly greater when the mites were kept under winter conditions throughout their life cycle (T1; $P<0.01$). The lowest longevity was observed when individuals were kept in winter conditions during a shorter period (T2 and T3) (Fig. 4).

The pre-oviposition period also differed among the four treatments ($F_{3,29}=64.46$, $P<0.01$), being significantly longer in individuals under the T1 and T3 conditions than

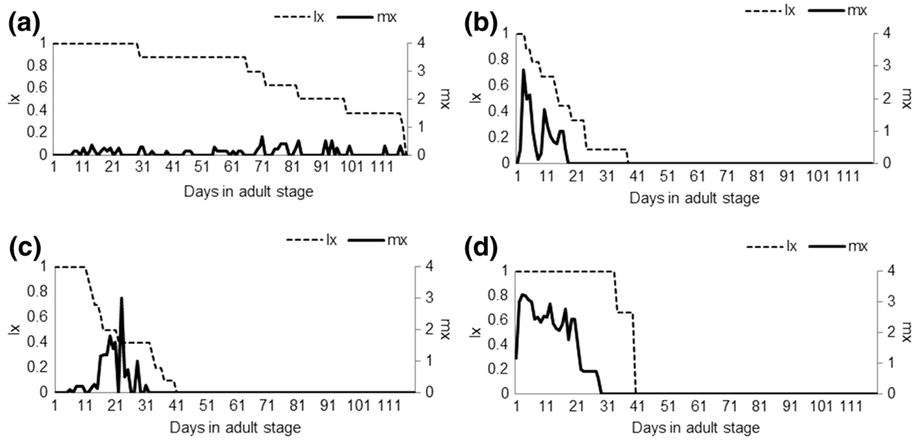

Fig. 3 Survival (lx, dashed lines) and age-specific fecundity (mx, solid lines) per day of *Neoseiulus californicus* under various seasonal conditions: **a** individuals under winter conditions (T1; 10 °C, L10:D14) from the larval stage onward; **b** individuals under winter conditions from larval to adult stages, then throughout the adult stage under spring conditions (T2; 25 °C, L14:D10); **c** individuals under spring conditions from larval to adult stages, then under winter conditions during only the first 15 days of adulthood before reestablishing spring conditions (T3); **d** individuals under spring conditions throughout the entire life cycle (T4). The daily survival and age-specific fecundity are plotted as a function of the number of days in the adult stage

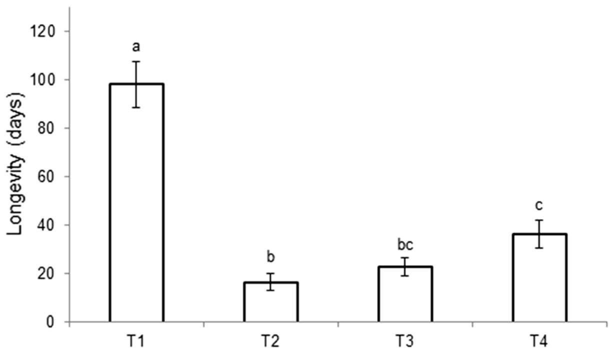

Fig. 4 Mean (± SE) longevity of *Neoseiulus californicus* under the different treatment conditions: T1, individuals maintained under winter conditions (10 °C, L10:D14) from the larval stage onward; T2, individuals kept under winter conditions from the larval to the adult stages and then placed under spring conditions (25 °C, L14:D10) throughout adulthood; T3, individuals maintained under spring conditions from larval to adult stages, then shifted to winter conditions during only the first 15 days of adulthood before reestablishing spring conditions; T4 (control), individuals held under spring conditions throughout the entire life cycle

under those of the treatment T2 and especially those of the T4 (Fig. 5a). The oviposition period also was significantly longer in individuals of treatment T1 than in those of the other three ($F_{3,25} = 27.92$, $P < 0.01$) (Fig. 5b).

The daily fecundity remained very low throughout the oviposition period when the females were under winter conditions from the larval stage onward (T1), or under winter conditions during only the first 15 days in the adult stage before reestablishing spring

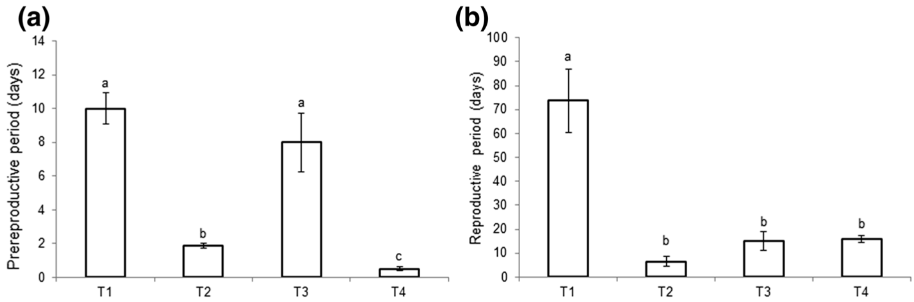

Fig. 5 Mean (± SE) pre-oviposition (**a**) and oviposition (**b**) period of *Neoseiulus californicus* females under the various treatment conditions: T1, individuals maintained under winter conditions (10 °C, L10:D14) from the larval stage onward; T2, individuals kept under winter conditions from the larval to the adult stages, then placed under spring conditions (25 °C, L10:D14) throughout adulthood; T3, individuals maintained under spring conditions from larval to adult stages, then shifted to winter conditions during only the first 15 days of adulthood before reestablishing spring conditions; T4 (control), individuals held under spring conditions throughout the entire life cycle

conditions (T3), than when the whole cycle took place under optimal conditions (T4). When females were under winter condition during only the preadult stages (T2) their daily fecundity was as high as under optimal conditions (T4) ($H_{3,30} = 18.685$, $P < 0.001$) (Fig. 6a). The mean total fecundity per female (Fig. 6b) was always the highest in the control treatment T4 ($F_{3,26} = 10.389$, $P < 001$).

Egg hatching (%) was high under all treatments, with differences ($P < 0.01$) between T1 (85%) versus T2, T3 and T4 (96.6, 100, and 100%, respectively). Offspring survival (number of adults surviving in the offspring per total number of eggs laid) was also high under all treatments, although highest in the control (T4; 100%): T1 (72%), T2 (92.2%) and T3 (92%) ($P < 0.01$). The percentage of adults surviving in the offspring under T1 was lower than under T2 and T3 ($P < 0.01$).

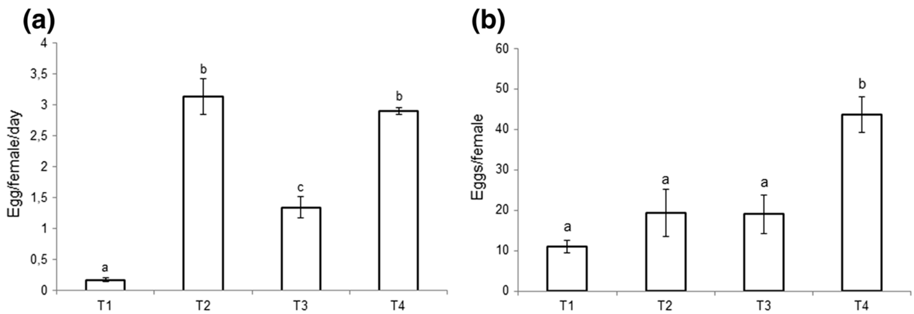

Fig. 6 Mean (± SE) daily (**a**) and total (**b**) fecundity of *Neoseiulus californicus* females under the various treatment conditions: T1, individuals maintained under winter conditions (10 °C, L10:D14) from the larval stage onward; T2, individuals kept under winter conditions from the larval to the adult stages, then placed under spring conditions (25 °C, L10:D14) throughout adulthood; T3, individuals maintained under spring conditions from larval to adult stages, then shifted to winter conditions only during the first 15 days of adulthood before reestablishing spring conditions; T4 (control), individuals held under spring conditions throughout the entire life cycle

Discussion

Winter is a crucial season for the survival of arthropods, especially in temperate regions (Kiritani 2006). The successful overwintering of natural pest predators enables their early seasonal colonization on crops, often resulting in an effective suppression of their prey (Landis et al. 2000). *Neoseiulus californicus* was present on various crops throughout the year in the horticultural belt of La Plata, Argentina, even under winter conditions and on crops grown outdoors, such as artichoke. In contrast, on corn, zucchini, and cherry tomato, *N. californicus* was largely absent, though the prey was present at a high percentage of the units sampled. Escudero and Ferragut (1999) also had found *N. californicus* on a smaller percentage of the crops present in winter than during the other seasons. In the present work, during spring and summer, *N. californicus* was recorded on more crops than during autumn and winter, and indeed the mite's presence on certain crops also occurred at the highest frequency during those seasons in association with the appearance of *T. urticae*. As the frequency of occurrence of *T. urticae* was quite high on raspberry and—particularly—cucumber crops, their proximity to strawberry could facilitate the dispersion towards this crop. Similary, even though *T. urticae* was absent on leek, this crop was associated with the presence of white flies and thrips and could be a source of these pests.

Escudero and Ferragut (2005) also found that the relationship between predator and prey was variable. The mite *T. kochi* and aphids are usually abundant on artichoke, but neither this mite nor the honeydew produced by the aphids are suitable alternative food for *N. californicus* (Gugole Ottaviano 2012). Artichoke could serve as a refuge for this predator as the dense structure of the plants plus the morphology of the compact leaves (i.e., large, hairy, and thick) could provide a favorable microclimate for refuge under adverse weather conditions, especially in autumn and winter. Moreover, the proximity of artichokes to a strawberry crop could favor an early colonization of the latter at a time when the pest is still at low densities. In turn, the aphid registered on artichoke, *Capitophorus eleagni* (Del Guercio) (Hemiptera: Aphididae), is specific to this crop, thus representing no risk for the cultivation of strawberries.

As Morewood (1993) argued, the diapause of phytoseiid mites can be facultative; certain species—or even particular populations—though not necessarily diapausing, would nevertheless be able to overwinter successfully (Wysoki and Swirski 1971; McMurtry et al. 1976; Overmeer 1985; Hart et al. 2002). The ability of *N. californicus* to enter diapause varies according to the mite's place of origin and the conditions of temperature and photoperiod. No diapause was reported for Japanese (Gotoh et al. 2005) and American (Jolly 2001; Hart et al. 2002) strains, whereas the incidence of diapause was 95.7, 16.1 (Jolly 2001), and 54–100% (Castagnoli et al. 1996) in British, Spanish, and Italian strains, respectively.

In the present study, individuals of *N. californicus* exposed in the laboratory to winter conditions of temperature and lighting from the larval stage throughout the life cycle had a long pre-oviposition period and a low oviposition rate, but did not enter diapause, as that state would involve a complete suspension of egg laying until the occurrence of more favorable conditions (Veerman 1992). Within that treatment, only one female did not lay eggs. Coombs and Bale (2014) found similar results when they exposed individuals of *Phytoseiulus macropilis* Banks to 15 °C and L11:D13 photoperiod.

When individuals were transferred to optimal (spring) conditions after being under winter conditions from the larval to the adult stage, their pre-oviposition period was short whereas their fecundity, though variable, was higher than under constant winter conditions.

Similarly, when the individuals were maintained under the optimal spring conditions from the larval to the adult stage and then transferred to winter conditions during the first 15 days of adulthood, the pre-oviposition period was long and the oviposition rate low. Once, however, the optimal conditions were restored, the daily fecundity per female became similar to that of the individuals that had stayed under optimal conditions throughout the entire life cycle. The low fecundity of the females recorded in these experiments under winter conditions coincided with previous field observations, in that few eggs of this predator had been registered in winter and then only on a few crops (i.e., raspberry, corn, artichoke, and strawberry; unpublished personal observation).

The criteria used to determine whether phytoseiid mites undergo reproductive diapause is the absence of oviposition and an elongation of pre-oviposition period of females to over 15 days (Fitzgerald and Solomon 1991; Bruce-Oliver et al. 1995; Jolly 2001; El Taj and Jung 2011). In the present study, this period became lengthened both in the individuals that underwent the whole developmental cycle under winter conditions and in those that were transferred to such conditions once they reached the adult stage, but in both instances the duration was shorter than 15 days.

The average conditions of temperature and photoperiod during the winter in the study region would significantly diminish the viability and development of eggs relative to offspring that developed under optimal conditions. Nevertheless, egg hatch was higher than 80% and egg-to-adult survival exceeded 70%.

Although this particular Argentine strain does not undergo a state of reproductive diapause, the fecundity of the females decreased significantly under winter conditions, yet they were able to survive at low temperatures. After winter, the daily fecundity per female of *N. californicus* populations of this horticultural belt of La Plata was found to return to the values reached under optimal conditions. This characteristic, among others, explains the high potential of this predator as a control agent of *T. urticae* in the strawberry crops of this region.

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