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Effect of pollens and preys on various biological parameters of the generalist mite *Cydnodromus californicus*

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Abstract

The generalist phytoseiid mite *Cydnodromus californicus* (McGregor) (Mesostigmata Phytoseiidae) is considered a very important biocontrol agent of the spider mite *Tetranychus urticae* Koch both in greenhouses and field. Its capacity to feed alternative foods allows the increase of the population in field, even when the primary prey is not available. To investigate the effect of various alternative food substances present in the Mediterranean agroecosystems on the biological parameters of *C. californicus*, laboratory trials were carried out using 17 pollens and 3 preys. As it was expected, *T. urticae* was the best food for both the postembryonic development and the oviposition rate (100% of attained adulthoods and 2.65 eggs/female/day were laid). Good results were obtained also with pollens of *Carpobrotus edulis* (L.) and *Scrophularia peregrina* L.: on both pollens, 84% of eggs reached the adulthood and the oviposition rate was 2.00 and 1.81 eggs/female/day for the two pollens respectively. Interesting results were obtained with the alternative prey *Petrobia hartii* (Ewing), very common on *Oxalis* spp., a weed widespread in Mediterranean orchards (72% of attained adulthoods and 0.57 eggs/female/day). On the other hand, the effect of *Mentha piperita* L. was not positive on the juvenile development (only 28% of eggs reached the adulthood), while it was positive on the oviposition rate (1.12 eggs/female/day).

Key words: *Cydnodromus californicus*, pollen, preys.

Introduction

Cydnodromus californicus (McGregor) (Mesostigmata Phytoseiidae) is considered one of the most important biocontrol agents of the two-spotted spider mite *Tetranychus urticae* Koch (Pickett and Gilstrap, 1986; García-Marí and González-Zamora, 1999; Easterbrook *et al*., 2001). It belongs to the Type II Selective Predators, preferably preying on spider mites of the genus *Tetranychus* (McMurtry and Croft, 1997), but able to develop also on different preys and on no-prey foods (Castagnoli and Simoni, 1999). *C. californicus* is an endemic species in various Mediterranean countries (Fauvel and Gendrier, 1992; McMurtry and Croft, 1997) and it is often found associated with spontaneous plants in various Italian agroecosystems (Vacante and Nucifora, 1986; Liguori and Castagnoli, 1989; Calvitti and Tsolakis, 1992). In Southern France apple orchards, this species prefers to live on ground cover plants and then to migrate towards trees infested by *Panonychus ulmi* (Koch) (Fauvel *et al*. 1993; Auger *et al*. 1999). It overwinters mainly as female on spontaneous herbaceous plants and starts its reproductive activity in March-April (Raworth *et al*. 1994). According to the latter authors, pollens of *Hordeum murinum* L. and *Stellaria media* (L.) play an important role for the early increase of phytoseiid population in field. However, little is known on the influence of various kinds of foods, present in *C. californicus* habitat, on the phytoseiid's biology.

The aim of this paper is to report on the importance of the spontaneous Mediterranean flora, as alternative food sources (pollen and host preys), through laboratory trials on their influence on various biological parameters of *C. californicus*, in order to evaluate their implication in Integrated Pest Management Programs.

Materials and methods

Predator, preys and pollens

C. californicus was collected on weeds, associated with *T. urticae* and bred in laboratory using plexiglas arenas (∅ 10 cm) (Swirski *et al*., 1970) on pollen of *Carpobrotus edulis* (L.). At least once a week different stages of *T. urticae* were added to the diet. The preys *Petrobia hartii* (Ewing) and *Polyphagotarsonemus latus* (Banks) were collected daily from infested *Oxalis* spp. and *Solanum nigrum* L. respectively, while *T. urticae* was reared on bean plants in greenhouse. The weed pollens used in the tests were collected in field when needed.

Experimental units and tests

The experimental unit (EU) consisted of a plexiglas arena (∅ 2.5 cm), as described by Swirski *et al*. (1970). To check the effects of various kinds of food on the postembryonic development, one egg was isolated in a cage and observed daily, at the same hour, until the young reached adulthood. To obtain eggs almost of the same age, about 40 ovipositing females were transferred in a plexiglas arena with abundant pollen for 24 hours. Afterwards, one egg of the predator was transferred with a fine brush from the arena to each EU. Each test

Note: The genus *Cydnodromus*, proposed by Muma (1961), was redescribed by Athias-Henriot (1977) taken into account criteria that well define groups of species (natural lineages) linked one to another beyond the idiosomal chaetotaxy, as proposed by Muma and Denmark (1968). Chant and McMurtry (2003), revised the genus *Neoseiulus* using only chaetotactic parameters, and put all species of the genus *Cydnodromus* inside the genus *Neoseiulus*. We consider incorrect this point of view and prefer to include *californicus* in the genus *Cydnodromus* as it defined by Athias-Henriot (1977).

was replicated 25 times. Food was abundantly supplied daily. Tests on adults were carried out on young fertilized females. To obtain them, 100 eggs of the predator were transferred, with a fine brush, from the culture arenas onto a new arena with abundant food. The newly emerged females and males were transferred to a new arena with abundant pollen of *C. edulis* for 2-3 days, to allow copulation. Afterwards, one female was isolated on each EU for ten days, observing its health status and counting the number of eggs/day. Different stages of preys or pollens were abundantly supplied daily. Twenty replicates were made for each test. All tests were carried out in a growth chamber set at 25 ± 1 °C, 70 ± 5% R.H. and a 16:8 (L:D) photoperiod.

Population growth study

The effect of the various kinds of foods on the populations growth of the predator was measured by the instantaneous rate of increase (r_i), as defined by Hall (1964) and Walthall and Stark (1997). This rate of population growth measures the population increase or decrease also after a short period of observation and is calculated according to the following equation:

$$r_i = \frac{\ln\left(\frac{N_f}{N_o}\right)}{\Delta t},$$

where N_f is the final number of animals, N_o is the initial number of animals and Δt refers to the number of days the experiment is run. Solving for r_i yields a rate of population increase similar to that obtained with the intrinsic rate of increase (r_m) (Walthall and Stark, 1997). Positive values of r_i show a growing population, $r_i = 0$ indicates a stable population while negative values of r_i indicate a declining population directed toward extinction (Walthall and Stark, 1997). Instantaneous rate of increase was calculated after 10 days in the adult tests.

Statistical analysis

A residual analysis was performed on the data to confirm the normality assumption prior to ANOVA. When homoscedasticity was not met (Brown-Forsythe test), the alternative no parametric ANOVA (Kruskal-Wallis test) was performed on the data. Differences were considered significant when 95% or 99% fiducial limits did not overlap. Analyses were computed using the software "Statistica" (StatSoft Inc., 2007).

Results

Different foods did not show any influence on the larval stage, which lasted about one day ($H_{20, 519} = 66.24$, $P < 0.0001$). However, significant differences were found for both the protonymph ($H_{20, 476} = 217.44$, $P < 0.0001$) and the deutonymph stage ($H_{18, 339} = 99.22$, $P < 0.0001$) among tests with the various foods. The longest protonymphal and deutonymphal periods were observed using *P. latus*. As a consequence, the longest postembryonic development was registered on *P. latus* (8.90 ± 0.66 days), while the shortest was registered on *S. nigrum* pollen (4.18 ± 0.12 days) (table 1) ($P < 0.05$). It should be mentioned that a short post-embryonic development did not correspond to a high survival. When *Mentha piperita* L. pollen was supplied, even if the postembryonic development lasted 5.33 days, only 28% of immatures reached adulthood. A similar duration was registered when supplying *T. urticae,* but in this case 100% of immatures became adults (table 1). High significant differences on the survival of young stages ($F_{19,80} = 18.85$, $P < 0.0001$) were also found taking into account the other foods (table 1). It should be mentioned that 11 foods allowed the immatures to reach adulthood, and only four of them were inadequate for the postembryonic development (table 1).

As far as the oviposition rate is concerned, it was strongly influenced by various kinds of foods ($H_{19, 2828} = 1343.34$, $P < 0.0001$). On different stages of *T. urticae* the predator oviposited the maximum number of eggs (2.65 eggs/female/day), while this value was lower on the other foods (table 2). A good oviposition rate (about 2 eggs/female/day) was obtained on pollens of *C. edulis* and *Scrophularia peregrina* L., and an acceptable oviposition rate (about 1 egg/female/day) on pollens of *M. piperita*, *S. nigrum*, *Chimonanthus fragrans* Lindley, *Aloe arborescens* Miller and *Cucurbita maxima* Duchesne. On the other hand, when the two alternative preys were supplied, the oviposition rate was very low (0.57 and 0.04 eggs/female/day for *P. hartii* and *P. latus*, respectively). The oviposition rate reached a peak immediately, showing a constant increasing trend during the test period on *T. urticae* (figure 1). Similar trends were also noted on pollens of *C. edulis* and *S. peregrina* ($P < 0.01$), while those obtained with pollens of *M. piperita*, *S. nigrum*, *C. fragrans*, *A. arborescens* and *C. maxima* were statistically different ($P < 0.01$). On these latter foods, the oviposition started after two-four days and the daily rate was statistically lower ($P < 0.05$) (figure 1, table 2). Moreover, about 40% of mortality was registered at the end of the test supplying *P. hartii*, while all the other foods, except *Lantana camara* L., allowed survival to more than 70% of females (table 2).

The instantaneous rate of increase calculated for ten days showed a high statistical difference for the various tests ($H_{19, 300} = 246.35$, $P < 0.0001$). As it can be noted in figure 2, *T. urticae* and five pollens had the best influence on the population increase, and other seven foods gave a positive r_i values. The instantaneous rate of increase was 0.00 on *C. maxima*, as this pollen did not allow completing the postembryonic development, though it did not show any negative influence on adults: no mortality and a satisfying oviposition rate (0.74 egg/female/day).

Discussion

According to Zhang and Croft (1994) feeding patterns, *C. californicus* larvae are considered "facultative feeding larvae" as they do not need energy to become protonymphs, although some nutritional activity was reported (Monetti and Croft, 1997; Palevsky *et al*., 1999). However, in our experiments the feeding of larvae did not influence the duration of the stage. The longest duration

Table 1. Duration (in days) of post embryonic stages of *C. californicus* (McGregor) on different kinds of food substances.

	Food	Eggs	Larvae	Protonymph	Deutonymph	Female	Male	Survival	
		Mean± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	Mean ± SE	%	
1	*Tetranychus urticae* Koch	1.48 ± 0.12	1.22 ± 0.12	1.34 ± 0.10 a	1.52 ± 0.10 a	5.64 ± 0.23 a	5.45 ± 0.21 ab	100.00 ± 0.00	a
2	*Chimonanthus fragrans* Lindley	1.40 ± 0.10	1.08 ± 0.06	1.25 ± 0.09 a	2.21 ± 0.18 b	6.18 ± 0.26 b	4.86 ± 0.59 a	96.00 ± 4.00	ab
3	*Aloe arborescens* Miller	1.44 ± 0.10	1.04 ± 0.04	1.16 ± 0.07 a	1.29 ± 0.09 a	4.93 ± 0.07 a	4.75 ± 0.16 a	88.00 ± 8.00	ab
4	*Carpobrotus edulis* (L.)	1.32 ± 0.10	1.08 ± 0.06	1.20 ± 0.08 a	1.24 ± 0.09 a	4.91 ± 0.25 a	4.60 ± 0.22 a	84.00 ± 4.00	ab
5	*Stellaria media* (L.)	1.24 ± 0.09	0.96 ± 0.04	1.65 ± 0.12 a	1.62 ± 0.14 ab	5.67 ± 0.29 a	5.25 ± 0.25 a	84.00 ± 11.66	ab
6	*Scrophularia peregrina* L.	1.52 ± 0.13	1.08 ± 0.06	1.86 ± 0.09 ab	1.54 ± 0.11 a	6.00 ± 0.12 b	5.89 ± 0.26 ab	84.00 ± 9.80	abc
7	*Solanum nigrum* L.	1.24 ± 0.09	1.00 ± 0.39	1.00 ± 0.47 a	1.00 ± 0.52 a	4.18 ± 0.12 a	4.11 ± 0.11 a	80.00 ± 8.94	abc
8	*Lotus ornithopodioides* L.	1.52 ± 0.10	0.93 ± 0.04	1.27 ± 0.10 a	1.26 ± 0.10 a	4.86 ± 0.24 a	4.96 ± 0.20 a	76.00 ± 7.48	abc
9	*Parietaria officinalis* L.	1.36 ± 0.10	1.12 ± 0.07	1.61 ± 0.10 a	1.79 ± 0.12 ab	5.50 ± 0.29 a	6.00 ± 0.44 b	76.00 ± 4.00	abc
10	*Petrobia hartii* (Ewing)	1.52 ± 0.12	1.20 ± 0.08	1.68 ± 0.10 a	1.71 ± 0.11 ab	6.67 ± 0.17 b	6.33 ± 0.29 b	72.00 ± 8.00	abc
11	*Polyphagotarsonemus latus* (Banks)	1.60 ± 0.10	1.32 ± 0.10	2.39 ± 0.17 b	2.94 ± 0.27 b	8.90 ± 0.66 c	8.75 ± 1.03 c	56.00 ± 9.80	bcd
12	*Lobularia maritima* (L.)	1.56 ± 0.12	1.04 ± 0.04	1.33 ± 0.11 a	1.67 ± 0.16 ab	6.00 ± 0.50 b	6.00 ± 1.00 b	48.00 ± 18.55	bcd
13	*Galium aparina* L.	1.48 ± 0.10	1.20 ± 0.08	1.40 ± 0.12 a	1.61 ± 0.25 ab	6.43 ± 0.20 b	7.00 ± 0.00 b	36.00 ± 9.80	cd
14	*Mentha piperita* L.	1.64 ± 0.13	1.08 ± 0.06	1.50 ± 0.12 a	1.60 ± 0.13 ab	5.33 ± 0.33 a	6.50 ± 0.50 b	28.00 ± 14.97	cd
15	*Dimorphoteca pluvialis* (L.) Moench	1.44 ± 0.10	1.24 ± 0.09	1.30 ± 0.10 a	1.82 ± 0.23 ab	6.00 ± 0.00 b	6.50 ± 0.50 b	12.00 ± 4.90	d
16	*Aptenia cordifolia* L.	1.60 ± 0.12	1.56 ± 0.17	3.11 ± 0.29 b	1.88 ± 0.13 ab	8.00 ± 0.00 c	7.00 ± 0.00 b	8.00 ± 4.90	d
17	*Lantana camara* L.	1.52 ± 0.10	1.60 ± 0.17	2.84 ± 0.21 b	1.67 ± 0.33 ab			0.00	e
18	*Geranium rotundifolium* L.	1.64 ± 0.10	1.00 ± 0.45	2.18 ± 0.19 b	1.50 ± 0.29 a			0.00	e
19	*Cucurbita maxima* Duchesne	1.56 ± 0.11	1.22 ± 0.11	4.00 ± 0.58 b	3.17 ± 0.46 b			0.00	e
20	*Boerhavia repens* L.	1.48 ± 0.10	1.24 ± 0.09	3.50 ± 0.31 b				0.00	e
21	Water	1.20 ± 0.08	1.30 ± 0.10	2.22 ± 0.17 b				0.00	e

* Different letters denote significant differences for a=0.05 (ANOVA or the non parametric Kruskal-Wallis test were performed on the data)

Table 2. Oviposition rate and survival of *C. californicus* females on different kind of food substances.

	Food	Eggs/female/day (Mean ± S.E.)*	Sum of eggs/test	Survival of females Days at the end of the test (Mean ± S.E.)*	N.	Ratio (Mean ± S.E.)*
1	*T. urticae*	2.65 ± 0.14 a	390	9.80 ± 0.14 ab	13	0.87 ± 0.09 ab
2	*C. edulis*	2.00 ± 0.15 bc	300	10.00 a	15	1.00 a
3	*S. peregrina*	1.81 ± 0.13 bc	272	10.00 a	15	1.00 a
4	*M. piperita*	1.12 ± 0.08 bcd	168	10.00 a	15	1.00 a
5	*S. nigrum*	1.04 ± 0.07 bcd	156	10.00 a	15	1.00 a
6	*C. fragrans*	0.91 ± 0.06 bcd	137	10.00 a	15	1.00 a
7	*A. arborescens*	0.90 ± 0.08 de	135	10.00 a	15	1.00 a
8	*C. maxima*	0.74 ± 0.07 de	111	10.00 a	15	1.00 a
9	*P. hartii*	0.57 ± 0.09 ef	66	7.73 ± 0.75 ab	9	0.60 ± 0.13 ab
10	*S. media*	0.23 ± 0.04 fg	33	9.66 ± 0.33 ab	14	0.93 ± 0.07 ab
11	*G. aparina*	0.21 ± 0.03 fg	32	10.00 a	15	1.00 a
12	*L. maritima*	0.17 ± 0.04 fg	26	10.00 a	15	1.00 a
13	*L. ornitophodioides*	0.13 ± 0.04 fg	17	8.60 ± 0.67 ab	11	0.73 ± 0.12 ab
14	*A. cordifolia*	0.10 ± 0.03 g	13	9.06 ± 0.66 ab	13	0.87 ± 0.09 ab
15	*P. latus*	0.04 ± 0.02 g	6	10.00 a	15	1.00 a
16	*B. repens*	0.04 ± 0.02 g	5	9.20 ± 0.36 ad	12	0.80 ± 0.11 ab
17	*G. rotundifolium*	0.03 ± 0.01 g	4	9.13 ± 0.59 ab	13	0.87 ± 0.09 ab
18	*P. officinalis*	0.00 g	0	8.93 ± 0.63 ab	12	0.80 ± 0.11 ab
19	*D. pluvialis*	0.00 g	0	9.93 ± 0.06 ab	14	0.93 ± 0.07 ab
20	*L. camara*	0.00 g	0	6.33 ± 0.74 bc	3	0.20 ± 0.11 bc
21	Water	0.00 g	0	3.80 ± 0.38 c	0	0.00 c

*Different letters denote significant differences for $a = 0.05$ (Kruskal-Wallis test).

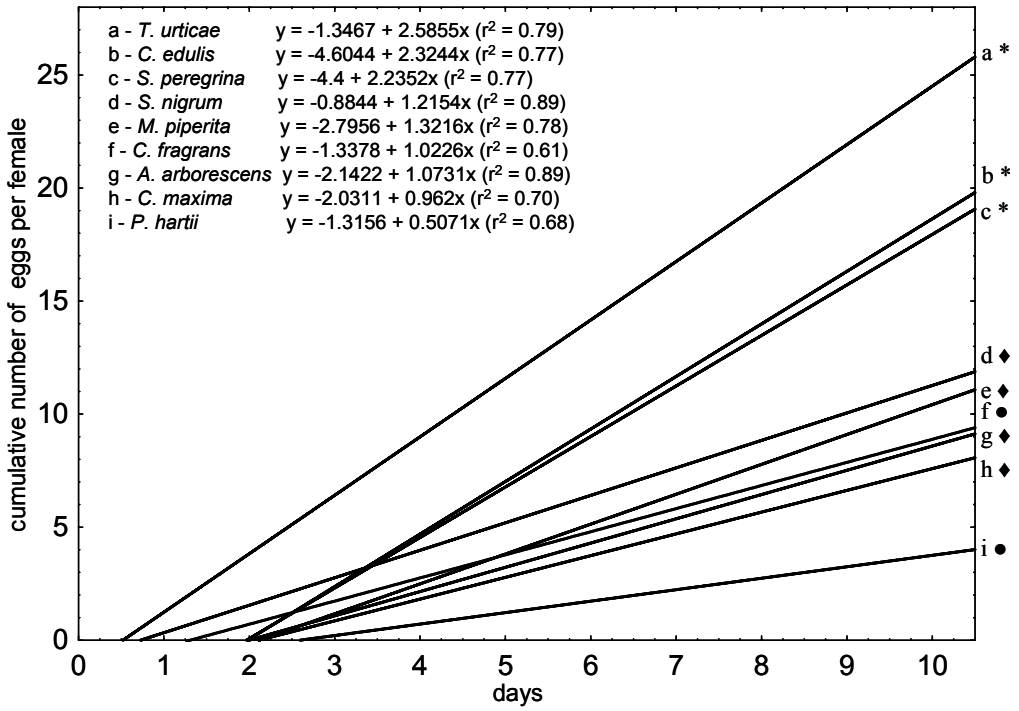

Figure 1. Cumulative oviposition of *C. californicus* as a function of time on the more positive kinds of foods. Symbols denote different slopes of regression lines (*t* test, $P < 0.05$).

of nymphal stage on *P. latus* could indicate a difficulty of the predator to adapt to a non-tetranychid prey, while it showed less difficulty to prey upon *P. hartii*, despite its size. This behaviour was also registered in adult tests confirming the preference of the phytoseiid towards tetranychid preys. *P. hartii* is strictly associated with *Oxalis* spp., weeds that are widely distributed in the Sicilian agricultural habitat from November to April. This association could represent a good alternative food for the predator during winter, when very few other preys or

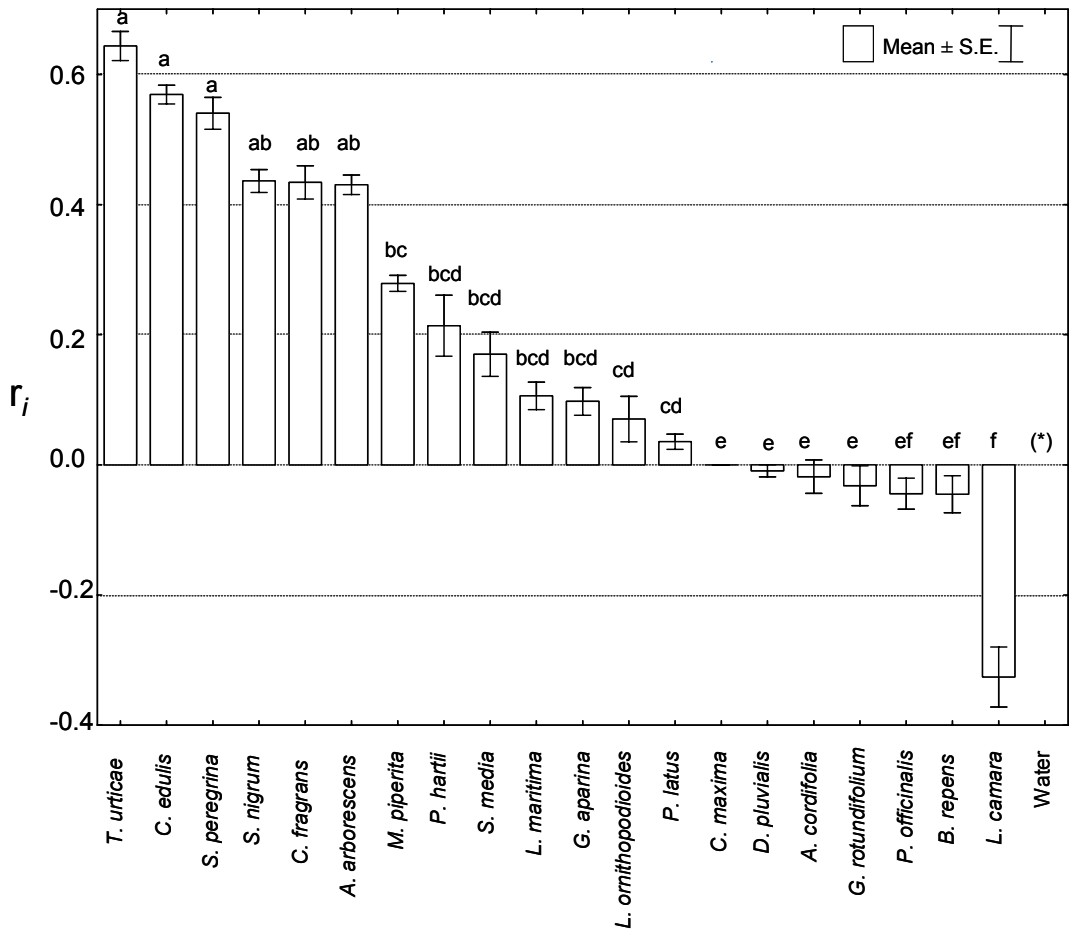

Figure 2. Instantaneous rate of increase of *C. californicus* on various kinds of food substances. Different letters denote significant differences for $P < 0.05$ (non parametric Kruskal-Wallis test). (*) r_i value was not calculated for water test because 100% of mortality was registered both in postembryonic development and oviposition rate tests.

pollens are present. As far as the influence of various kinds of food on both the postembryonic development and the oviposition rate is concerned, a correspondence was not always found. For example, all the nymphs died after 7 days on pollen of *C. maxima*, but all females survived until the end of the test laying about one egg/female/day. This fact was unexpected, as phytoseiid females usually lay eggs only on foods considered adequate for the postembryonic development of their progeny (Ragusa Di Chiara and Tsolakis, 1995). On the contrary, the oviposition rate was very low on *S. media*, even if the duration of the postembryonic development was very short and almost with no mortality. Similar results on this pollen were also reported for *Amblyseius andersoni* (Chant) (Ragusa Di Chiara and Tsolakis, 1995). *C. californicus* females showed a very quick adaptation to their elective prey *T. urticae.* This behaviour was also reported for mass-reared strains of *C. californicus* on alternative foods (Castagnoli and Simoni, 1999). However, it was observed that the species needs some days to adapt to other new tempting foods before oviposition. On the other hand, the preoviposition period of *A. andersoni* was longer on *T. urticae* than on pollen of *C. edulis* (Tsolakis and Ragusa Di Chiara, 1994).

As far as the influence of various kinds of foods on the population growth is concerned, it was noted that the predator is able to increase its population on a great number of foods: 13 out of 20 (3 preys and 10 pollens). This fact means that the species has many possibilities for surviving and increasing its population in field, especially in early spring when the primary prey *T. urticae* is absent.

Considerations

It is worthwhile mentioning that the presence of food alone is not enough to guarantee the population growth. Climatic conditions also play an important role for both population growth and dispersal. As a matter of fact, Auger et al. (1999), found that when the temperature reaches 12 °C, the phytoseiid starts to be active showing an ambulatory dispersal and at 15 °C about, already 90% of young stages reaches adulthood (Gotoh *et al.*, 2004). These conditions are very common in the Mediterranean countries in early spring, indicating that the species has real possibilities to be a good biocontrol agent in field conditions. However, other phytoseiid species are more common than *C. californicus* in Sicilian orchards, but no data are available on their presence on spontaneous vegetation surrounding the crops. It

should be mentioned that *C. californicus* is present also in other Sicilian crops of economic importance, i.e. various herbaceous crops as strawberry, tomato, eggplant etc., where *T. urticae* is considered the key pest. Further investigations are required to verify the distribution of the species on the various components of the agroecosystems in order to confirm its economic importance with field data.

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