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The effects of different temperatures and diets on the biology of *Cales noacki* Howard (Hymenoptera: Aphelinidae), a parasitoid of the citrus woolly whitefly

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Abstract: The biology of *Cales noacki* Howard (Hymenoptera: Aphelinidae), a particular parasitoid of the woolly whitefly, *Aleurothrixus floccosus* Maskell (Homoptera: Aleyrodidae), was investigated under laboratory conditions, where the effects of different temperatures [18, 22, 26, 30, 34, 18/26, 26/34 °C] and the longevity of adults on different diets [sugar water (10%), water with honey (10%), water, honeydew of *A. floccosus*, 1st instar larvae of *A. floccosus*, or no food] were observed. The longest developmental time of *C. noacki* was identified at 18 °C (♀: 49.0 and ♂: 48.5 days) and the shortest time was at 26 and 30 °C constant temperatures (♀: 19.1, 18.5 and ♂: 19.0, 18.9 days). The developmental threshold of the parasitoid was calculated as 10.0 °C and the total effective temperature was 384.6 degree-days. The longest lifespan of adult individuals was at 18 °C (♀: 8.6 and ♂: 8.3 days) and the shortest was under the fluctuating temperature of 26-34 °C (♀: 6.2 and ♂: 6.2 days). The preoviposition period of *C. noacki* females lasted about 0.8 days, the oviposition period was about 6.4 days, and females parasitized an average of 37.4 hosts during this period. The lifespan of the adults was the longest when fed sugar water (10%) (♀: 7.4 and ♂: 7.0 days) and the shortest, when without a nutrient (♀: 1.1 and ♂: 1.3 days).

Key words: *Cales noacki*, temperature, developmental time, lifespan, diet

Farklı sıcaklık ve besin ortamlarının turunçgil pamuklu beyazsineğinin parazitoiti, *Cales noacki* Howard (Hymenoptera: Aphelinidae)'nin biyolojisine etkileri

Özet: Turunçgil pamuklu beyazsineği, *Aleurothrixus floccosus* Maskell (Homoptera: Aleyrodidae)'un spesifik parazitoiti, *Cales noacki* Howard (Hymenoptera: Aphelinidae)'nin biyolojisi farklı sıcaklıklarda [18, 22, 26, 30, 34, 18/26, 26/34 °C] ve erginlerinin yaşam süreleri ise farklı besin ortamlarında [şekerli su (%10), ballı su (%10), su, *A. floccosus*'un balımsı maddesi, *A. foccosus*'un 1. larva dönemi, besinsiz] laboratuvar koşullarında incelenmiştir. *Cales noacki* ergin öncesi dönemlerinin gelişme süresi en uzun 18 °C'de (♀: 49.0 ve ♂: 48.5 gün), en kısa ise 26 ve 30 °C sabit sıcaklıklarda (♀: 19.1, 18.5 ve ♂: 19.0, 18.9 gün) tespit edilmiştir. Parazitoitin gelişmeye başlayabilmesi için gerekli en düşük sıcaklığın 10.0 °C, bir dölünü tamamlayabilmesi için gerekli etkili sıcaklıklar toplamının ise 384.6 gün-derece olduğu hesaplanmıştır. Diğer taraftan, aynı sıcaklıklarda ergin bireylerin yaşam süreleri en uzun yine 18 °C sabit sıcaklıkta (♀: 8.6 ve ♂: 8.3 gün), en kısa ise 26/34 °C değişken sıcaklıkta (♀: 6.2 ve ♂: 6.2 gün) bulunmuştur. *Cales noacki* dişilerinin preovipozisyon süresi ortalama 0.8 gün sürerken, ovipozisyon süresi ise ortalama 6.4 gün devam etmiş ve bu sürede bir dişi ortalama olarak 37.4 adet konukçuyu parazitlemiştir. Ergin dişiler farklı besinlerle beslendiklerinde en uzun süreyle % 10'luk şekerli su verildiğinde (♀: 7.4 ve ♂: 7.0 gün) yaşamışlar, en kısa ise besin olmayan (♀: 1.1 ve ♂: 1.3 gün) ortamda yaşamışlardır.

Anahtar sözcükler: *Cales noacki*, sıcaklık, gelişme süresi, ömür, besin

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Introduction

Cales noacki Howard (Hymenoptera: Aphelinidae) is a specific entomophagous parasitoid of the woolly whitefly, *Aleurothrixus floccosus* Maskell (Homoptera: Aleyrodidae), which is one of the most important citrus pests. *C. noacki* was brought from South America to Europe (Onnilon and Onnilon, 1972; Carrero, 1975) and was first seen in France in 1966 (Onnilon, 1969). In 1994, the parasitoid, with its host, *A. floccosus,* was first recorded in Turkey [in Hatay (Harbiye)] (Ulusoy and Uygun, 1996). Over several years, it spread with its host to whole citrus plantations in the East Mediterranean region of Turkey.

It has been reported that the use of *C. noacki* is more effective than chemicals in controlling *A. floccosus* (DeBach and Rose, 1976; Longo et al., 1985; Chermiti and Onnilon, 1992; Vivas, 1992; Barbagallo et al, 1993). Indeed, *C. noacki* is the most effective known natural enemy of *A. floccosus*, and has been used successfully in many countries for the biological control of whitefly (Miklasievicz and Walker, 1990; Del-Bene and Gargani, 1991; Vivas, 1992; Barbagallo et al., 1993; Katsoyannos et al., 1997). For example, Katsayannos et al. (1997) reported that after releasing *C. noacki* in Greece, the parasitoid - despite having some natural enemies - appeared to be the main contributor to an observed reduction of *A. floccosus*.

The presence of *C. noacki* holds promise for efforts to control the proliferation of whitefly in Turkey (Ulusoy and Uygun, 1996; Ulusoy et al., 2003). However, it is first necessary to be able to rear, and release *C. noacki* into the field and support its existence if biological control is to be effective.

In this study, the biology of the parasitoid was studied under laboratory conditions to determine the longevity of adults when fed different diets and to identify conditions suitable for mass breeding of *C. noacki*.

Materials and methods

Sour orange (*Citrus aurantium* L.) saplings were used as host plants for *C. noacki* rearing. Firstly, *Aleurothrixus floccocus* was reared in a climate room on these plants. In another climate room, *C. noacki* collected as pupae from the field were reared on the whitefly. To ensure continuous production, saplings were obtained regularly each month and, when necessary, placed in the whitefly rearing room. In turn, citrus plants infested with many *A. floccosus* were placed in the parasitoid room.

Both *A. floccosus* and *C. noacki* stocks were maintained in a growth chamber at 25 °C and 65 ± 5% relative humidity (RH) under a 16:8 h light: dark (L:D) cycle.

Determination of the effects of different temperatures on the developmental time of immature stages of *Cales noacki*

Groups of three sour-orange saplings on which only a single leaf was left per plant (after removing all other leaves) were placed into climate cabinets at constant temperatures of 18, 22, 26, 30, and 34 ± 1 °C or at controlled fluctuating temperatures of 18/26 [night/day] ± 1 °C and 26/34 [night/day] ± 1 °C respectively. *Aleurothrixus floccosus* adults were collected with an aspirator in the rearing room and released into plastic jars whose topsides were covered by tulle and then placed onto the saplings. *A. floccosus* adults were kept on the saplings for 24 hrs to allow them to oviposit, and then removed. Hatched larvae were allowed to develop until they reached the 2nd larval instar, and *C. noacki* adults newly emerged from pupae were released onto the larvae. Parasitoid adults were removed after 24 hrs and all of the experiments were checked daily. Experiments were carried out at 65 ± 5% RH under a 16:8 h L:D cycle.

Determination of the effects of different temperatures on the lifespan of *Cales noacki*

To determine the longevity of *C. noacki* adults at different temperatures, 40 newly emerged female and male parasitoid adults were maintained under either constant temperatures (18, 22, 26, 30 and 34 ± 1 °C) or fluctuating temperatures (18/26 or 26/34 ± 1 °C. Parasitoid adults were put into petri dishes and covered by tulle (3 × 11 cm^2). Sugar water (10% w/v) absorbed into pieces of sponge was given as a nutrient. Dishes were examined every 12 hrs to count the surviving parasitoids. Experiments were carried out at 65 ± 5% RH under a 16:8 h L:D cycle.

Determination of the lengths of the preoviposition, oviposition and postoviposition periods of *Cales noacki*

To determine the length of the preoviposition period of *C. noacki*, a single male and female pair of newly emerged adults were released onto saplings (one pair per sapling) bearing different immature stages of *A. floccosus*. These adults were removed with an aspirator after 0.5, 1.0, 1.5, 2.0, 2.5 and 3.0 days, and each interval was repeated four times. The period between the start of the experiment and the day when the parasitizing first began was accepted as the preoviposition period.

To determine the length of the oviposition period, newly emerged female and male parasitoids were kept in glass tubes for a length of time equivalent to the preoviposition period and then released onto saplings on which *A. floccosus* of different immature stages was present. Adults of *C. noacki* were transferred to another sapling every 12 hrs and this process was repeated until the adults were dead. In this way, the time points of the first and last egg laying events of the parasitoid were determined. The period between the final egg lay and the parasitoid's death was accepted as the postoviposition period. Experiments were repeated with 12 pairs of the parasitoid. Sugar water (10% w/v) absorbed into pieces of sponge was given as a nutrient. Experiments were conducted in climate cabinets at 26 ± 1 °C, 65 ± 5% RH, under a 16:8 h L:D cycle.

Determination of the longevity of *Cales noacki* adults when fed on different diets

To determine the longevity of adults of *C. noacki* in environments without a nutrient or with different nutrients, newly emerged adults were given access to: water alone, sugar water (10% w/v), water with honey (10% v/v), honeydew of *A. floccosus*, and first instar larvae of *A. floccosus*. Parasitoid cultures were examined every 12 hrs until the adults were dead. Water, sugar water, and water with honey were given by saturating pieces of sponge with the solutions; honeydew of *A. floccosus* was given by applying it with a brush into the petri dish. The study set up entailed 30 replications of each treatment, and the entire study and was repeated twice. Experiments were carried out in climate cabinets at 26 ± 1 °C, 65 ± 5% RH, and under a 16:8 h L:D cycle.

Evaluation of data

Data were analyzed by using the SPSS 10.0 package program and following Steel and Torrie (1960) and Karman (1971) analysis of variance (ANOVA) was applied to means. Differences between means were evaluated with Duncan's test. A *t* test was applied to the results of the survival times of females and males maintained at different temperatures and to their longevity under different nutrients.

The effect of temperature on developmental rate (1/days) was calculated by linear regression. The minimum developmental temperature threshold for the parasitoid was found by extrapolating the regression line ($T_o = a/b$). The degree-day requirements were determined as the inverse of the linear equation slope (DD = 1/b) after Yasuda (1982) and Sharov (2004).

Results

Effects of different temperatures on the developmental time of immature stages of *Cales noacki*

The egg-laying, larval, and pupal stages of *C. noacki* could not be examined directly because of the woolly materials secreted by its host, *A. floccosus*. Therefore, the length of the egg-to-adult period was used to determine the developmental time of the immature stages of *C. noacki*.

It was observed that the developmental period of the parasitoid got shorter with increasing temperature (Table 1). The longest development period was at 18 °C (49.0 and 48.5 days for females and males, respectively) and the shortest was at 26 and 30 °C (Table 1). The lengths of the developmental periods of *C. noacki* at fluctuating temperatures (18/26 and 26/34 °C) were between the constant temperature 22 and 26 °C (Table 1). No significant differences in developmental times of females and males were observed at any of the temperatures, except for the 18/26 °C fluctuating temperature in which the development time of females was longer ($df = 19$; $t = 2.38$; $P = 0.028$) (Table 1).

The eggs of *A. floccosus* did not hatch when cultured at 34 °C, a constant temperature (Table 1). This experiment was repeated at 32 °C and, again, no

Table 1. Developmental time of the immature stages and lifespans of *Cales noacki* females and males at different temperatures.

Temp. (°C)	Developmental time (days)				Longevity (days)			
	♀		♂		♀		♂	
	n	Mean ± SE (min. - max.)	n	Mean ± SE (min. - max.)	n	Mean ± SE (min. - max.)	n	Mean ± SE (min. - max.)
18	27	49.0 ± 0.46 a^xA^y (43-54)	11	48.5 ± 0.88 aA (40-50)	27	8.6 ± 0.22 a^xA^y (7-11)	29	8.3 ± 0.38 aA (7-11)
22	22	36.5 ± 0.42 bA (34-41)	13	36.5 ± 0.64 bA (34-40)	32	8.0 ± 0.26 abA (5-11)	12	7.5 ± 0.33 abA (5-10)
26	23	19.1 ± 0.44 eA (16-24)	10	19.0 ± 0.80 eA (16-24)	33	7.3 ± 0.45 bA (2-13)	16	7.1 ± 0.29 bcA (4-11)
30	24	18.5 ± 0.27 eA (17-21)	15	18.9 ± 0.36 eA (17-21)	21	7.0 ± 0.32 bcA (5-10)	18	7.0 ± 0.39 bcA (5-9)
34	No host development				No host development			
18/26	12	32.4 ± 0.96 cA (27-38)	9	29.2 ± 0.94 cB (26-34)	37	7.6 ± 0.19 bA (6-10)	12	7.4 ± 0.26 abA (6-10)
26/34	12	21.0 ± 0.60 dA (18-25)	8	22.1 ± 0.85 dA (19-26)	19	6.2 ± 0.48 cA (4-10)	16	6.2 ± 0.34 cA (4-8)

*[x] Means within a column followed by the same letter are not significantly different by Duncan's test (*P* = 0.05).
[y] Means within a line followed by the same letter are not significantly different by *t* test (*P*= 0.05).

hatching occurred. Therefore *A. floccosus* individuals were cultured initially at 26 °C until the majority had reached the second larval instar, and then transferred to 34 °C after which the parasitoids were released onto them. As a result, individuals of *A. floccosus* as well as the parasitoids died at this temperature before they completed development. It was concluded that temperatures above 30 °C are lethal to both *A. floccosus* and *C. noacki* during development. The latter depended on the whitefly larvae for its survival.

Because there was no statistical difference between the developmental times of males and females of *C. noacki* (Table 1), both sexes were combined to produce a regression curve of development time versus temperature (Figure 1). A strong relationship between total developmental time of *C. noacki* and temperature (R^2 = 0.834; *P* = 0.011) was found, and the development period shortened significantly with increasing temperature (Figure 1). Furthermore, by

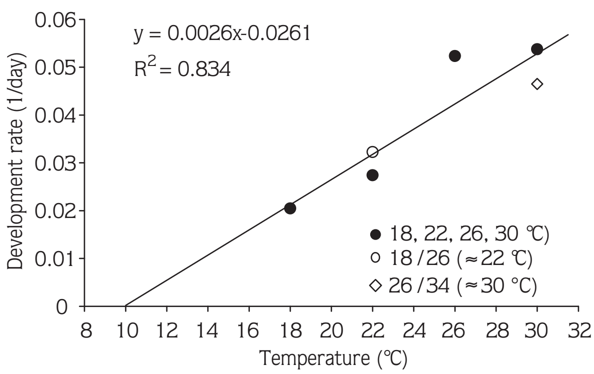

Figure 1. Relationship between developmental time of immature stages of *Cales noacki* females and temperature.

taking the climate data of the geographical region (Adana, Turkey) into consideration, it was calculated that the minimum temperature necessary for males and females of *C. noacki* to undertake development is 10.0 °C and that the total effective temperature necessary for growth of one offspring is 384.6 degree-days. Therefore, theoretically, a *C. noacki* female might be able to produce 9-10 offspring per year in Adana.

Effects of different temperatures on the lifespan of *Cales noacki*

The lifespan of male and female adults of *C. noacki* were longest under the constant temperature of 18 °C (8.6 and 8.3 days for females and males, respectively) and were shortest under the fluctuating temperature of 26-34 °C (6.2 and 6.2 days). The lifespan of adult males and females were not significantly different at any temperature (Table 1), although females did appear to live slightly longer than males, as was also the case for the immature stages. According to the results, (Table 1) it could be said that the longevity of *C. noacki* adults is inversely related to the temperature, because as the temperature increased the longevity shortened significantly.

Lengths of the preoviposition, oviposition and postoviposition periods of *Cales noacki*

The preoviposition period of *C. noacki* was an average of 0.8 days at 26 °C. Some of the parasitoid females began to lay eggs right after being released onto the whitefly larvae and some of them after 1.5 days (Figure 2). The oviposition period of *C. noacki* was found to be 6.4 days at 26 °C (Figure 2) and a parasitoid female could parasitize an average of 37.4 hosts within this period. Adult females parasitized a minimum of 35 and a maximum 42 hosts during their lifespan.

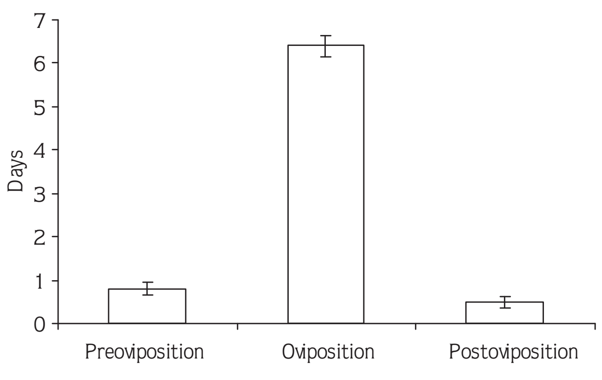

Figure 2. Preoviposition, oviposition and postoviposition periods (days) of *Cales noacki* at 26 ± 1 °C.

The postoviposition period of *C. noacki* was 0.5 days at 26 °C, and the parasitoid adults died soon after they laid their last eggs (Figure 2).

C. noacki females laid the maximum amount of eggs on the second day of their adult lives (9.1 eggs/♀/day). Moreover, it was observed that the quantity of the eggs started to decline from day 3 until day 10, when they laid their last egg (Figure 3).

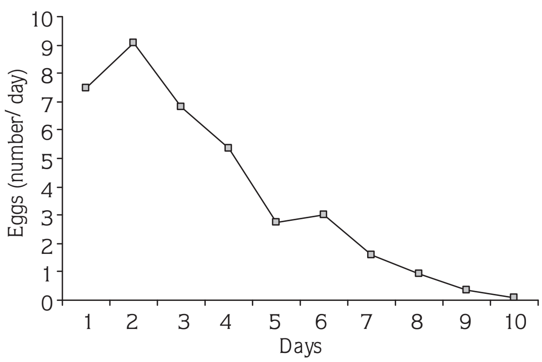

Figure 3. Average egg numbers laid by *Cales noacki* females during their longevities.

Longevity of *Cales noacki* adults when fed on different diets

Adult females and males of *C. noacki* lived longest when they were fed 10% sugar water (7.4 and 7.0 days). Water with 10% honey produced the next highest survivorship (4.9 and 4.5 days). Predictably, parasitoid adults receiving no nutrient (or water) lived the shortest (1.1 and 1.3 days) (Table 2). The differences in longevity produced by 10% sugar water, water with honey, and no nutrient were significant; the differences in longevity of parasitoids fed water, honeydew of *A. floccosus*, and first instar larvae of *A. floccosus* were not significant (Table 2).

The difference in longevity of *C. noacki* females and males fed first instar larvae of *A. floccosus* was significant ($df = 44$; $t = 2.29$; $P = 0.026$); on the other hand, any other differences between females and males were not significant (Table 2).

Table 2. Longevity of *Cales noacki* when fed on different diets at 26 ± 1 °C.

Food	Longevity (days)			
	♀		♂	
	n	mean ± S.E. (min. - max.)	n	mean ± S.E. (min. - max.)
Sugar water (10% w/v)	40	7.4 ± 0.13 a[x]A[y] (5 – 9)	22	7.0 ± 0.18 aA (6 – 8.5)
Water with honey (10% v/v)	43	4.9 ± 0.13 bA (3 – 6)	17	4.5 ± 0.38 bA (2 – 7)
Water	30	2.4 ± 0.16 cA (1 – 4)	30	2.1 ± 0.22 cA (0.5 – 4.5)
Honeydew of *A. floccosus*	48	2.7 ± 0.10 cA (1.5 – 4.5)	12	2.8 ± 0.33 cA (1 – 4.5)
First instar larvae of *A. floccosus*	38	2.5 ± 0.13 cA (1 – 4)	22	2.0 ± 0.17 cB (1 – 4)
No food	48	1.1 ± 0.05 dA (0.5 – 2)	12	1.3 ± 0.21 dA (0.5 – 2.5)

[x] Means within a column followed by the same letter are not significantly different by Duncan's test (P = 0.05).
[y] Means within a line followed by the same letter are not significantly different by *t* test (P = 0.05).

Discussion

The developmental time of immature stages of *C. noacki* decreased as temperature increased from 18 to 30 ºC (Table 1). The longest developmental time was at 18, and the shortest was 26 and 30 ºC respectively. These findings are consistent with the results of several previous studies. Lo Pinto (1993) indicated that *C. noacki* completed its development in 23-24 days at 24 ± 1 °C and 60-70% RH. Other researchers reported that the parasitoid completed its development in 20 days at 25-27 °C (Laudonia and Viggiani, 1986) and in 22 days at 26.7 ± 1.1 °C (Miklasiewicz and Walker, 1990). On the other hand, Abbasi (1980) found that *C. noacki* completed its development in only 21 days at 22 °C. This discrepancy might be caused by strain-specific differences or differences in environmental factors such as humidity, light: dark cycle or host plant.

It was concluded that both *A. floccosus* and the parasitoid depending on the host could not live over 30 ºC, as these temperatures had a lethal effect on the whitefly and parasitoid as well. In line with our work, it was noted that *C. noacki* becomes inactive at very high temperatures in summer and that significant parasitoid death occurs at temperatures above 35 °C (Chermiti and Onnilon, 1992). Similarly, parasitism decreased during the high temperatures of summer in Spain, whereas lower temperatures caused the parasite population to increase (Carrero, 1975; Garrido et al., 1976; Santaballa et al., 1980). Many researchers have noted that the developmental time of other parasitoids shortens with increasing temperature (Powell and Bellows, 1992; Şengonca et al., 1994; López and Botto, 1997; Manzano et al., 2000) whereas very high temperatures have a lethal effect both on the host and the parasitoid (Deng and Tsai, 1998; Bell et al., 2003).

The longevity of both males and females of *C. noacki* was affected by the increasing temperature. As with the developmental time, the longevity of male and female parasitoids was found to be similar to each other (Table 1). In previous studies, Abbasi (1980) reported that *C. noacki* females lived for 12.2 days. In addition, Lo Pinto (1993) determined that unmated adult females and males lived for 8.77 and 8.03 days, respectively, similar to the lifespan observed for male and female parasitoids maintained at 18 and 22 °C in the present study (Table 1).

There are many studies that have reported that the longevity of parasitoids decreases with increasing temperature. Powell and Bellows (1992) determined that the longevity of *Eretmocerus* sp. (Hymenoptera: Aphelinidae), which is a parasitoid of *Bemisia tabaci* Gennadius (Homoptera: Aleyrodidae), was 11.6 days at 20 °C and 5.4 days at 29 °C. Similarly, it was noted that the longevity of *Amitus bennetti* Viggiani and Evans (Hymenoptera: Platygasteridae), parasitoid of *Bemisia argentifolii* Bellows and Perring (Homoptera: Aleyrodidae) at 25 °C was shorter than that of those kept at 15 or 20 °C (Drost et al., 1999). In contrast, Şengonca et al. (1994) found that increasing temperature had no effect on the longevity of *Eretmocerus debachi* (Rose and Rosen) (Hymenoptera: Aphelinidae), a parasitoid of *Parabemisia myricae* (Kuwana) (Homoptera: Aleyrodidae).

It was observed that some females of *C. noacki*, like some other aphelinid species, began to deposit eggs shortly after emerging and prior to mating (Figure 2). In a similar way, it was reported that *E. debachi* (Şengonca et al. 1994) and *Amitus fuscipennis* MacGown and Nebeker (Hymenoptera: Platygastridae) (De Vis et al., 2002), both parasitoids of *A. floccosus*, had no preoviposition periods, but started to lay eggs right after they emerged from the pupa, as in the present study.

Abbasi (1980) noted that *C. noacki* females lived for 12.2 days at 22 °C and parasitized 47.4 hosts during their lifespan, whereas Lo Pinto (1993) stated that they parasitized 41.5 hosts on average at 24 °C. Note that the numbers of eggs laid in those two studies are slightly higher than the 37.4 eggs at 26 °C observed in the present study. Culture conditions such as the host plant that the whitefly lived on might explain the different levels of fecundity.

Females *C. noacki* deposited a maximum number of eggs on the second day of their lives and then the number of eggs decreased day by day (Figure 3). Similarly, Lo Pinto (1993) indicated that *C. noacki* females laid a maximum number of eggs on the second day of their adult lives at 24 °C. Şengonca et al. (1994) stated that *E. debachi* females laid most of their eggs during the first three days of their adult lives, with the maximum being laid on the second day.

It was stated that the adults of *C. noacki* feed on nutrients which contain carbohydrate such as plant nectars and honeydew of the whitefly (liquid excretions of Homoptera, consisting largely of sugars and amino acids) (Manzano et al., 2000). There have also been some studies that suggest that the longevity of parasitoids not given honey, honeydew or nectar is much reduced (Idoine and Ferro, 1988). In this study as well, *C. noacki* preferred mostly sugar water or honey compared to the other nutrients (Table 2).

However, during the experimental period, after sugar water or honey, *C. noacki* preferred water, honeydew and the first instar larvae of the whitefly equally. This could be because the parasitoid might have preferred each nutrient for its survival at a minimum level. Furthermore, it was determined that those not given any nutrients (including water) lived for 2 days at most (Table 2).

Considering these results, *C. noacki* could live longer when reared on nutrients containing a carbohydrate; indeed, they preferred especially sugar water among the nutrients with carbohydrate to meet their energy requirements for parasitizing the host after emerging from pupae.

Lo Pinto (1993) determined that, when fed honey and sugar, mated *C. noacki* females and males lived for 9.4 and 7.2 days, respectively, and unmated ones lived for 8.8 and 8.0 days, and that within this period they did not feed on their hosts. Lo Pinto (1993) also reported that unfed parasitoids lived for less than 3 days. These results are similar to our own findings. However, it was also observed that very few of the parasitoids actually consumed any of the offered first instar larvae of *A. floccosus*. Şengonca et al. (1994) determined that when *E. debachi* adults were fed different types of diets, the parasitoids that were fed 10% sugar water lived the longest. Furthermore, it was noted that honey is a more nutritious food than the honeydew of *Trialeurodes vaporariorum* (Westwood) (Homoptera: Aleyrodidae) for *Encarsia formosa* Gahan (Hymenoptera: Aphelinidae) (Lenteren et al., 1987).

In conclusion, *C. noacki* is a fairly efficient parasitoid of *A. floccosus*. It can be easily reared in the laboratory and released to the field as needed. All the data obtained from the study provide useful new information about the biology of *A. floccosus*. However, further studies are required to better understand the parasitoid and to give it greater recognition for use in pest control. The present study of *C. noacki* is a fundamental first step toward achieving that goal.

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References

Abbasi, M. 1980. Recherches sur deux homoptères fixés des citrus *Aonidiella aurantii* Mask. (Hom. Diaspididae) et *Aleurothrixus floccosus* Mask. (Hom. Aleyrodidae). Cah. de la Rech. Agron. 35: 1-168.

Barbagallo, S., S. Longo, C. Rapisarda and G. Siscaro. 1993. Status of the biological control against citrus whiteflies and scale insects in Italy. Proc. Int. Soc. Citriculture. 3: 1216-1220.

Bell, H.A., G.C. Marris, F. Smethurst and J.P. Edwards. 2003. The Effect of host stage and temperature on selected developmental parameters of the solitary endoparasitoid *Meteorus gyrator* (Thun.) (Hym., Braconidae). J. Appl. Ent. 127: 332-339.

Carrero, J.M. 1975. Primera contributional al estudio de la biologia de la "mosca blanca" de los agrios, *Aleurothrixus floccosus* Mask., en la region valenciana. IV. Parasitismo por *Cales noacki* How. An. INIA Ser. Prot. Veg. 9: 153-162.

Chermiti, B. and J.C. Onnilon. 1992. A propos de la presence en Tunisie de deux nouvelles especes d'aleurodes nuisibles aux agrumes, *Aleurothrixus floccosus* (Maskell) et *Parabemisia myricae* (Kuwana) (Homoptera: Aleyrodidae). Fruits. 47: 405-411.

DeBach, P. and M. Rose. 1976. Biological control of woolly whitefly. California Agriculture. 30: 4-8.

Del-Bene, G. and E. Gargani. 1991. Osservazioni su *Aleurothrixus floccosus* (Mask.) (Hom.: Aleyrodidae) e sul suo antagonista *Cales noacki* How. (Hym. Aphelinidae) in Toscana. Redia. 74: 11-126.

Deng, Y.X. and J.H. Tsai. 1998. Development of *Lysiphlebia japonica* (Hymenoptera: Aphidiidae), a parasitoid of *Toxoptera citricida* (Homoptera: Aphididae) at five temperature. Florida Entomologist. 81: 415-423.

De Vis, R.M.J., L.E. Fuentes and J.C. van Lenteren. 2002. Life history of *Amitus fuscipennis* (Hym., Platygastridae) as parasitoid of the greenhouse whitefly *Trialeurodes vaporariorum* (Hom., Aleyrodidae) on tomato as function of temperature. J. Appl. Ent. 126: 24-33.

Drost, Y.C., Y.T. Qui, C.J.A.M. Posthuma-Doodeman and J.C. van Lenteren. 1999. Life-history and oviposition behaviour of *Amitus bennetti*, a parasitoit of *Bemisia argentifolii*. Entomologia Experimentalis et Applicata. 90: 183-189.

Garrido, A., J. Tarancon, T. Del Busto and M.C. Martinez. 1976. Repartición y estudio poblacional de *Aleurothrixus floccosus* Mask. a nivel del árbol y equilibrio con su parásito *Cales noacki* How. An. I.N.I.A. Serv. Prot.Veg. 6: 89-121.

Idoine, K. and D.N. Ferro. 1988. Aphid honeydew as a carbohydrate source for *Edovum puttleri* (Hym.: Eulophidae). Environ. Entomol. 17: 941-944

Karman, M. 1971. Denemelerin kuruluşu ve değerlendirme esasları. T.C. Tar. Bak. Zir. Gn. Md. Yayınları Böl. Zir. Müc. Araştır. Enst., Bornova, İzmir.

Katsoyannos, P., K. Ifantis and D.C. Kontodimas. 1997. Phenology, population trend and natural enemies of *Aleurothrixus floccosus* (Hom.: Aleyrodidae) at a Newly Invaded Area in Athens, Greece. Entomophaga. 42: 619-628.

Laudonia, S. and G. Viggiani. 1986. Observations on the immature stages of *Cales noacki* Howard (Hymenoptera: Aphelinidae). Bolletino del Laboratorio di Entomologia Agraria 'Filippo Silvestri', Italy. 43: 21-28.

Lenteren, J.C. van, A. van Vianen, H.F. Gast and A. Kortenhoff. 1987. The parasite-host relationship between *Encarsia formosa* Gahan (Hymenoptera: Aphelinidae) and *Trialeurodes vaporariorum* (Westwood) (Homoptera: Aleyrodidae). XVI: Food effects on oogenesis, oviposition, life span and fecundity of *Encarsia formosa* and other hymenopterous parasites. J. Appl. Ent. 103: 69-84.

Longo, S., C. Rapisarda and A. Russo. 1985. Results of the biological control of *Aleurothrixus floccosus* (Maskell) in citrus orchards of eastern Sicily. Atti XIV Congresso Nazionale Italiano di Entomologia sotto gli auspici dell'Academia Nazionale Italiana di Entomologia, della Societa Entomologica Italiana e della International Union of Biological Sciences. 28 maggio-1 giugno. 21: 841-848.

López, S.N. and E.N. Botto. 1997. Biology of a South American population of *Eretmocerus* sp. (Hymenoptera: Aphelinidae) Attacking the Greenhouse Whitefly. Biological Control. 9: 1-5.

Lo Pinto, M. 1993. Ultreriori notizie bioetologiche su *Cales noacki*. (Hym. Aphelinidae). Estratto da Phytophaga. 4: 93-111.

Manzano, M.R., J.C. van Lenteren, C. Cardona and Y.C. Drost, 2000. Development time, sex ratio, and longevity of *Amitus fuscipennis* MacGown & Nebeker (Hymenoptera: Platygasteridae) on the Greenhouse Whitefly. Biological Control. 18: 94-100.

Miklasiewicz, T.J. and G.P. Walker. 1990. Population dynamics and biological control of the woolly whitefly (Homoptera: Aleyrodidae) on citrus. Environ. Entomol. 19 (5): 1485-1490.

Onnilon, J.C. 1969. A propos de la présence en France d'une nouvelle espèce d'Aleurode nuisible aux citrus *Aleurothrixus floccosus* Mask. (Homopt., Aleurodidae). C.R. Acad. Agr. Fr. 55: 937-941.

Onnilon, J.C. and J. Onnilon. 1972. Contribution à l'étude de la dynamique des populations d'Homoptères infeodes aux agrumes. III. Introduction dans les Alpes-Maritimes de *Cales noacki* How. (Hym. Aphelinidae) parasite d'*Aleurothrixus floccosus* Mask. (Hom.) (Aleyrodidae). C.r. Hebd. Séanc. Acad. Agr. Fr. 58: 365-703.

Powell, D.A. and T.S. Bellows. 1992. Development and reproduction of two populations of *Eretmocerus* species (Hymenoptera: Aphelinidae) on *Bemisia tabaci* Genn. (Homoptera: Aleyrodidae). Environ. Entomol. 21: 651-658.

Santaballa, E., C. Borras and P. Polomer. 1980. Lucha contra la mosca blanca de los citricos *Aleurothrixus floccosus* Mask. Bol. Serv. Plagas. 6: 109-118.

Sharov, A. 2004. Development of poikilothermus organisms, degree-days. In: Quantitative Population Ecology. Dept. of Entomology, Virginia Tech, Blackburg, VA. (http://www.gypsymoth.ento.vt.edu/~sharov/PopEcol/popecol.html)

Steel, R.G.D. and J.H. Torrie. 1960. Principles and procedures of statistics. Mc Graç-Hill Book Co., New York.

Şengonca, Ç., N. Uygun, M.R. Ulusoy and U. Kersting. 1994. Laboratory studies on biology and ecology of *Eretmocerus debachi* Rose and Rosen (Hymenoptera: Aphelinidae) the parasitoid of *Parabemisia myricae* (Kuwana) (Homoptera: Aleyrodidae). J. Appl. Ent. 118: 407-412.

Ulusoy, M.R. and N. Uygun. 1996. Two new potential pests in the East Mediterranean Region of Turkey: *Aleurothrixus floccosus* (Maskell) and *Paraleyrodes minei* Iaccarino (Hom.: Aleyrodidae). Turkish Journal of Entomology. 20: 113-121.

Ulusoy, M.R., G. Vatansever, L. Erkılıç and N. Uygun. 2003. Pest status of *Aleurothrixus floccosus* (Maskell) (Hom.: Aleyrodidae) and Its Parazitoid, *Cales noacki* Howard (Hymenoptera: Aphelinidae) in the East Mediterranean Region of Turkey. Anzeiger für Schädlingskunde. 76: 163-169.

Vivas, A.G. 1992. Present status of whitefly on citrus in Spain, and control guidelines. Seminaire de la commission de technique, le 2 et 3 Septembre, Antalya - Turquie, pp. 1-19.

Yasuda, M. 1982. Influence of temperature on some of the life cycle parameters of Citrus red mite, *Panonychus citri* (McGregor) (Acarina: Tetranychidae). Jap. J. Appl. Ent. Zool. 26: 52-57.