Turk J Agric For
26 (2002) 119-124
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Development, Survival and Reproduction of Three Coccinellids Feeding on *Hyalopterus pruni* (Geoffer) (Homoptera: Aphididae)

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Received: 09.05.2001

Abstract: The development, survival and fecundity of three aphidophagus coccinellid species, *Scymnus apetzi* (Mulsant), *Scymnus subvillosus* (Goeze) and *Exochomus nigromaculatus* (Goeze), were studied under laboratory conditions (25 ± 1, 65 ± 5% RH and 16 L/8D). Development time from egg to adult was 20.4, 17.1 and 16.7 days for *S. apetzi, S. subvillosus* and *E. nigromaculatus,* respectively. Mortality rate from egg to adulthood was highest for *S. apetzi* (37.9%) followed by *S. subvillosus* (36.3%) and *E. nigromaculatus* (25.7%). Duration of the oviposition period was 58.6, 64.9 and 75.3 days, and the total number of eggs per female was 492.8, 224.9 and 428.5 for *S. apetzi, S. subvillosus* and *E. nigromaculatus*, respectively. According to the life table parameters, net reproduction rate per female (R_0), the intrins rate of increase (r_m), and mean generation time (T_0) were 137.5, 0,121 and 40.7 for S. apetzi; 69.9, 0.110 and 38.3 for *S. subvillosus*, and 157.2, 0.134 and 37.7 for *E. nigromaculatus.* The results obtained here provide information about the biology of three coccinellids that might be useful for the utilization of these predators in IPM programs against *H. pruni.*

Key Words: *Scymnus apetzi, Scymnus subvillosus, Exochomus nigromaculatus*

Hyalopterus pruni (Geoffer) (Homoptera: Aphididae) ile Beslenen Üç Coccinellid Türünün Gelişme ve Üremesi

Özet: Bu çalışma *Hyalopterus pruni* (Geoffer) ile beslenen üç coccinellid türü (Scymnus apetzi (Mulsant), *Scymnus subvillosus* Goeze ve *Exochomus nigromaculatus* Goeze)'nün laboratuvar koşullarında ergin öncesi dönemlerinin gelişme süresi, ölüm oranı ve üreme gücünün incelenmesi amacıyla yürütülmüştür. Araştırma 25 ± 1 ºC sıcaklık %65 ± 5 orantılı nem ve 16 saat aydınlatmalı iklim kabininde yürütülmüştür. Elde edilen sonuçlara göre yumurtadan ergine gelişme süresi *S. apetzi, S. subvillosus* and *E. nigromaculatus* için sırasıyla 20.4, 17.1 ve 16.7 gün olarak bulunmuştur. Ergin öncesi dönemde en yüksek ölüm oranı *S. apetzi* (%37.9)'de görülmüş onu sırasıyla *S. subvillosus* (%36.3) ve *E. nigromaculatus* (%25.7) izlemiştir. Ovipozisyon periyodu sırasıyla 58.6, 64.9 ve 75.3 gün süren *S. apetzi, S. subvillosus* ve *E. nigromaculatus* dişileri bu sürede sırasıyla 492.8, 224.9 ve 428.5 yumurta bırakmışlardır. Elde edilen verilerden hesaplanan yaşam çizelgesi paremetreleri; net üreme gücü (R_0), kalıtsal üreme yeteneği (r_m), ve ortalama döl süresi (T_0) *S. apetzi* için 137.5, 0,121 ve 40.7, *S. subvillosus* için 69.9, 0.110 ve 38.3 ve *E. nigromaculatus* için ise 157.2, 0.134 ve 37.7 olarak bulunmuştur. Bu çalışmada üç coccinellid türünün biyolojik özelliklerinin belirlenmesine yönelik olarak elde edilen sonuçlar *H. pruni*'ye karşı yürütülecek entegre zararlı yönetimi programlarında yararlı bilgiler sağlayabilir.

Anahtar Sözcükler: *Scymnus apetzi, Scymnus subvillosus, Exochomus nigromaculatus*

Introduction

Hyalopterus pruni (Geoffer) (Hom., Aphididae) is an important economically damging pest of stone fruit trees, including apricot, plum and peach, in the Van region in the east of Turkey (Toros et al., 1996). It causes direct damage by sucking plant sap, which induces plant deformation and indirect damage by the development of dense production of honeydew. Moreover, it was also reported as a virus vector (Bodenheimer and Swirski, 1957). The control of this pest has heavily relied on insecticides. In biological control agent surveys against *H. pruni*, many indigenous natural enemies were found. Among these, coccinellid species *Exochomus nigromaculatus* (Goeze), *Scymnus apetzi* (Mulsant) and *Scymnus subvillosus* (Goeze) have been observed as common predators, showing ability to reduce pest populations to significantly low levels. Öncüer (1991) has also considered these species as important natural enemies of *H. pruni* in stone fruit trees. Many factors are important in evaluating the success of these natural enemies as biological control agents of *H. pruni*. There are relatively few studies on the biology of *E.*

nigromaculatus and many species belonging to the genus Scymnus including *S. apetzi* and *S. subvillosus*, and thus more information is needed about their biology on specific prey. It is known that food (prey) plays an important role in the development, survival and reproduction of insects (Hagan et al., 1976; Gibson et al., 1992). Here, we studied the development, survival and fecundity of *E. nigromaculatus*, *S. apetzi* and *S. subvillosus*, fed with *H. pruni* under controlled laboratory conditions to obtain further information concerning the biological control of aphids.

Materials and Methods

The predators used in this study were collected from apricot and plum trees and cultured on apricot trees infested with *H. pruni* as prey at 25 ± 1ºC, 65 ± 5% RH and 16L:8D photoperiod. *H. pruni* was collected from apricot and plum plantations. Eggs taken from mass culture of the predator were reared to adult size and newly laid eggs from these adults were transferred into plum leaf disks placed upside down on wet blotting paper in cells (Ø 3.5 cm). The hatching time and mortality of eggs were determined by daily observations. Larvae hatching from eggs were transferred individually into similar cells containing *H. pruni*. The length of development time as well as the mortality of the larvae and pupae were observed daily. Newly emerged adults were randomly paired and kept in cells with prey. To study preoviposition, oviposition, postoviposition period and adult longevity, as well as numbers of eggs laid per female per day and mated pairs were observed daily until they died. In addition, the hatching ratio of predators' eggs was determined at five-day intervals during the oviposition period. Sex ratio was determined after preparation of genitalia according to Uygun (1981) from the adults reared.

All experiments were carried out at 25 ± 1ºC, 65 ± 5% RH and 16L:8D photoperiod in a temperature cabinet. Experiments were arranged in a completely randomized design with 18, 24 and 26 replicates in the developmental stage and 10, 14 and 13 replicates in the adult stage for *S. apetzi*, *S. subvillosus* and *E. nigromaculatus* respectively.

Data Analysis: Differences in developmental time, longevity, and fecundity were tested by analysis of variance (ANOVA). If significant differences were detected, multiple comparisons were made using Duncan's Multiple Range test (P = 0.05). Differences in sex ratio were tested by the chi-square test (P = 0.05).

Population growth rates were calculated according to Andrewartha and Birch (1970) and Southwood (1978):

$$1 = \Sigma\, e^{-r*x}\, l_x * m_x \qquad (1)$$

in which x= age in days, r = intrinsic rate of increase, l_x = age-specific survival, and m_x = age-specific number of female offspring.

After r was computed for the original data (r_{all}), the differences in r_m- values were tested for significance by estimating the variance using the jack-knife method facilitated calculation standard errors of r_m estimates (Sokal and Rohlf, 1981, Meyer et al., 1986). The jack-knife pseudo-value r_j was calculated for the n samples using the following equation:

$$r_j = n \times r_{all} - (n-1) \times r_i \qquad (2)$$

The mean values of (n – 1) jack-knife pseudo-values for each treatment were subjected to analysis of variance. Duncan's Multiple Range test was used to compare mean growth rates (P= 0.01).

Each step of the above mentioned analysis was conducted using the Statgraphics software package (Statistical Graphics Corporation, 1988).

Results and Discussion

The embryonic developmental time was longest for *S. apetzi*, which was significant compared with that of the other two. There were no significant differences between *S. subvillosus* and *E. nigromaculatus* (Table 1). The post-embryonic developmental time (four larval stages plus the pupal stage) was longest for *S. apetzi* with 14.8 days and shortest for *S. subvillosus* with 12.4 days, and there was statistical difference between these two species. The fourth larval stage and pupal stage were longer than any of the other stages for all predators tested. The total developmental time (egg to adult) of *S. apetzi* was significantly longer than that of *S. subvillosus* and *E. nigromaculatus*. This was due to the fact that *S. apetzi* showed a longer developmental time in the egg and pupa stages than the other two predators tested (Table 1).

The mortality rate of egg stage was highest for *S. apetzi* (31.03%) and the lowest for *E. nigromaculatus* (20%). In immature stages, mortality occurred only in the first larval stage for the three predators. It occurred

Table 1. Mean duration of egg and immature stages of three coccinellid fed on *Hyalopterus pruni*.

Predator species	n*	Duration of Egg stage mean±SE	Post-embryonic developmental time (days) 1st stage mean±SE	2nd stage mean±SE	3rd stage mean±SE	4th stage mean±SE	Pupa mean±SE	Larva + Pupa mean±SE	Egg to adult mean±SE
S. apetzi	18	5.7±0.5 a	1.6±0.3 b	1.5±0.3 b	1.3±0.6 a	2.6±0.7a	7.9±0.7 a	14.8 ±0.7 a	20.4±0.6 a
S. subvillosus	24	4.6±0.6 b	1.8±0.6 ab	1.3±0.5 b	1.3±0.7 a	2.4±0.5 a	5.6±0.7 b	12.4±0.9 b	17.1±1.1 b
E. nigromaculatus	26	4.3±0.6 b	2.1±0.3 a	1.9±0.4 a	1.8±0.8 a	2.9±0.5 a	4.7±0.5 c	13.4±0.9 ab	17.7±1.8 b

Means within column followed by the same letter are not statistically different by Duncan test (P = 0.05)
*Number of replicates represent the number that survived to adulhood.

in the pupal stage for *S. apetzi*. Total mortality (from egg to adult) of the two Scymnus species was close to each other but higher than that of *E. nigromaculatus* (Table 2).

There is very limited information about the biology of species belonging to the genus *Scymnus*. Immature developmental time was reported to be 16.8 days at 25ºC by Kawauchi (1983) for *Scymnus (Pullus) hoffmanni* Weise, which is similar to the value obtained in our study for *S. subvillosus*. Naranjo et al. (1990) found that the mortality rate of *Scymnus frontalis* (F.) in immature stages was 18.7% at 25ºC; this value is lower than the one we obtained for both *Scymnus* species. The differences between the data concerning mortality rate and development time obtained in our study and those in the literature could be related to species and food (prey) differences.

Table 3 gives the average duration of preoviposition, oviposition, postoviposition and longevity. The preoviposition period was longest for *S. subvillosus* and shortest for *S. apetzi*. There were significant differences among the three predator species tested. The oviposition and postoviposition period of *E. nigromaculatus* was longest, followed by *S. subvillosus* and *S. apetzi* (Table 3). Significantly differences were found only between *S. apetzi* and *E. nigromaculatus* in respect to oviposition and postoviposition period. The longevity of *S. apetzi* females was also less than that of the other species, but not statistically different from that of *S. subvillosus*.

The fecundity of *S. subvillosus* was lowest, with production an average of 224.9 eggs/female. In the other predator species tested, the total numbers of eggs per female were not statistically different from each other. The number of eggs laid per *S. apetzi* female per day was highest and there were significantly differences among the three predator species in regard to eggs/female/day (Table 3). The hatching ratio of *E. nigromaculatus*' eggs was highest (average 80%), followed by *S. subvillosus* (average 75%) and *S. apetzi* (average 69%). At the beginning and middle of the oviposition period, the hatching ratios of the three predators' eggs were high, but towards the end of the oviposition period, this ratio started to decrease (Figure 1). While the decrease in the hatching ratio of eggs was gradual for *E. nigromaculatus* and *S. subvillosus*, it showed fluctuations for *S. apetzi*. The decreasing in the hatching ratio of eggs at the end of the oviposition period was probably due to the fact that some eggs laid in this period were not fertilized.

The sex ratio of the offspring of each predator was close to 1:1 (53.6:46.4, 56.1:43.9, and 57.4:42.6 for *S. apetzi*, *S. subvillosus* and *E. nigromaculatus* respectively) according to the chi-square test (P = 0.05).

The survival rates of adults for each predator decreased gradually after a peak in egg production; this was due to the fact that death occurred at advanced ages. While total eggs laid per female were lower for *E.*

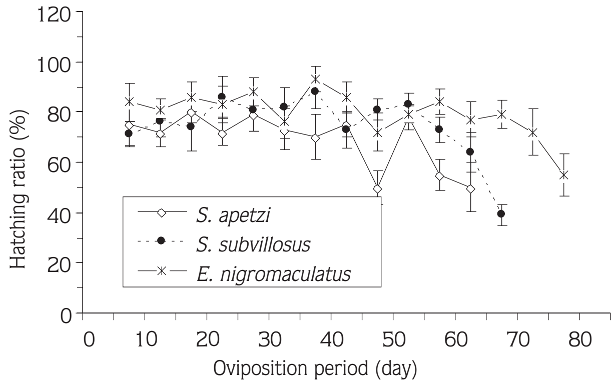

Figure 1. Hatching ratio of eggs in relation to oviposition period.

Table 2. Mortality rates of egg and immature stages of three coccinellid fed on *Hyalopterus pruni*.

Predator species	n	Mortality of Egg stage	Mortality of immature stages (%)					Total Mortality (Egg to adult)
			1st stage	2nd stage	3rd stage	4th stage	Pupa	
S. apetzi	29	31.03	5.00	0.00	0.00	0.00	5.30	37.93
S. subvillosus	44	25.00	15.15	0.00	0.00	0.00	0.00	36.34
E. nigromaculatus	35	20.00	7.14	0.00	0.00	0.00	0.00	25.71

Table 3. Longevity and fecundity of three coccinellid fed on *Hyalopterus pruni*.

Predator species	n	Duration of different periods (days)			Longevity (days) mean ± SE	No. of eggs per female	
		Pre-oviposition mean ± SE	Oviposition mean ± SE	Post-oviposition mean ± SE		per day mean ± SE	total mean ± SE
S. apetzi	10	4.8 ± 0.8 c*	58.6 ± 9.5 b	7.7 ± 3.6 b	70.6 ± 13.8 b	9.4 ± 1.9 a	492.8 ± 78.8 a
S. subvillosus	14	7.4 ± 0.7 a	64.9 ± 16.2 ab	9.8 ± 5.8 ab	82.2 ± 21.2 ab	3.7 ± 1.8 c	224.9 ± 76.5 b
E. nigromaculatus	13	5.6 ± 0.7 b	75.3 ± 13.9 a	13.6 ± 4.0 a	94.4 ± 11.0 a	5.9 ± 1.2 b	428.5 ± 64.8 a

Means within column followed by the same letter are not statistically different by Duncan test (P = 0.05)

Table 4. The net reproduction rate (R_0), the intrinsic rate of increase (r_m) and generation time (T_0) of three coccinellids fed on *Hyalopterus pruni*.

Predator species	Reproduction rate (females/female)	Intrinsic rate of increase (females/female/day)	Generation time (days)
S. apetzi	137.5	0.122 ± 0.0013 b	40.7
S. subvillosus	69.9	0.110 ± 0.0011 c	38.3
E. nigromaculatus	157.2	0.134 ± 0.0010 a	37.7

r_m values followed by different letters are significantly different (P = 0.01).

nigromaculatus than for *S. apetzi*, the net reproduction rate (R_0) and the intrinsic rate of increase (r_m) of *E. nigromaculatus* were the highest (Table 4). The reason for the highest net reproduction rate (R_0 = 157.2 females/female) and intrinsic rate of increase (r_m = 0.134 females/female per day) could be explained by the lower mortality rate, shorter immature developmental time and earlier peak in reproduction (Figure 2). The generation time (T_0) was similar for all predator species tested (Table 4). Kawauchi (1985) reported that the net reproduction rate (R_0) of *S. hoffmanni* was 126.9, which is different from the values obtained for both species in our study. On the other hand, Izhevsky and Orlinsky (1988) reported that total number of eggs laid by the mealybug predator, *S. reunioni* Fursch, was 171.1. Gibson et al. (1992) reported that *S. frontalis* feeding on *Acyrtosiphon pisum* (Harris) laid 413.6 eggs. Values obtained by Izhevsky and Orlinsky (1988) and by Gibson et al. (1992) are relatively close to those for *S. subvillosus* and *S. apetzi* respectively, but are slightly lower.

Conclusions

Based on the literature and this study, differences in developmental time and survival rate of immature stages of predator species could be explained by the influence of two factors: species differences and food suitability. In addition to these factors, differences in reproduction may be due to their oviposition capacity.

Results from this study might provide useful information for the utilization of these predators in IPM

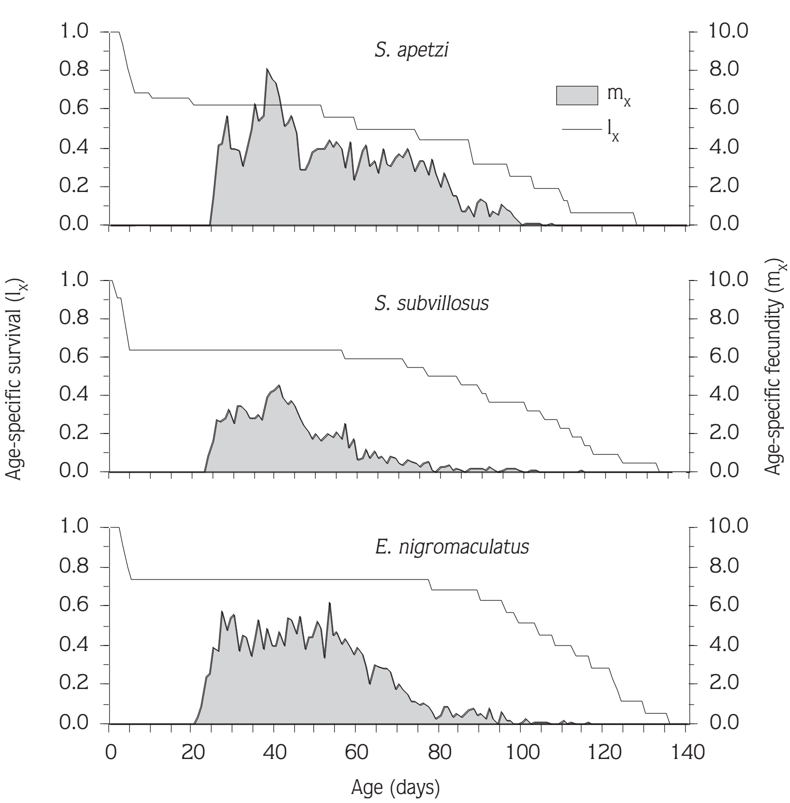

Fig. 2. Age-specific survival rate (l_x) and age-specific fecundity (m_x) of three coccinellid species fed on *Hyalopterus pruni.*

programs in stone fruit trees. However, before drawing any further conclusions it is suggested that, under various conditions, developmental time, mortality rate, longevity and fecundity, and functional and numerical responses of these predators at different prey densities should be studied.

Acknowledgments

We express thanks to E. Şekeroğlu, Plant Protection Department of Çukurova University, for reviewing the manuscript.

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