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# Demographic study of the reproductive potential of pear psylla, *Cacopsylla pyri*

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## Abstract

Longevity and fecundity of pear psylla adults, *Cacopsylla pyri* (L.) (Homoptera: Psyllidae), were studied in Greece under field conditions, during 1991/92 and 1992/93. Net fecundity (mean fecundity of cohort) of the overwintered females (winter form) was low (24.1 and 43.4 eggs per female for 1991/92 and 1992/93 respectively) because only a small fraction of the females survive reproductive diapause. Surviving females, however, are capable of producing a relatively high number of eggs (135.0 and 151.9 eggs per female for the two seasons respectively). Net fecundity of summer form females was very high in spring (343.2 and 406.8 eggs per female for 1992 and 1993 respectively), relatively high in early autumn (130.4 and 192.5 eggs per female) and very low in summer (21.9 and 46.5 eggs per female). Male longevity was in all cases shorter than that of female. Longevity of both sexes of the summer form was higher in spring and autumn (for females it ranged from 22.3 to 28.4 days) than it was in summer (for females it ranged from 14.3 to 17.4 days).

## Introduction

Pear psylla, *Cacopsylla pyri* (L.) (Homoptera: Psyllidae), is the most serious pest of the pear tree in Europe. In Greece, the pear psylla completes six generations per year. Adults emerging in autumn undergo reproductive diapause and have a winter form. Overwintered females oviposit the following February–March, giving rise to the first generation of adults of the summer form, in April. Summer form females have a short pre-oviposition period (3–7 days) and during the period from late April to late October, five overlapping generations are produced (Bonnemaison & Missonier, 1956; Nguyen, 1972; Atger, 1979; Broumas et al., 1989; Stratopoulou & Kapatos, 1992).

Infestation by pear psylla fluctuates considerably throughout the year. Very high levels of infestation are usually observed during the spring and relatively high levels in the autumn, while infestation is low during the first infestation period (February–March) and in the summer. In the region of Magnesia (Greece) rates of increase up to 22 times from late winter–early spring (February–March) to late spring (May) and rates of

decrease up to 10 times from late spring to summer were recorded for the egg population of pear psylla (Stratopoulou & Kapatos, 1992). It is not known whether these changes are due to variation in the fecundity or to changes in mortality factors during the year. A study was carried out in Greece, region of Magnesia, to estimate under field conditions demographic parameters determining reproduction of *C. pyri* such as adult longevity, fecundity, etc. This information was considered essential for optimum planning of control strategies during the year, since it would determine the potential for infestation of the adult population of pear psylla at various times of the year.

## Materials and methods

**Experimental procedure.** The study was carried out during 1991/92 and 1992/93 at an experimental field located 22 km from the town of Volos. The pear trees were of the variety 'Kristali' (Tsakoniki) and were kept free from chemical treatments during the study period.

They were medium sized (4-5 m high) and approximately the same age (20-25 years).

In mid-January of each year, before oviposition by overwintered pear psylla females had occurred, a sufficient number of two year growth branches from 12 trees in 1991/92 and 10 in 1992/93 were enclosed with fine mesh nylon bags after it was made sure that no pear psylla or predators were present. The selected nylon mesh provided adequate ventilation and minimized any possible 'green house' effect on the caged adults.

Six times during 1991/92 (31/10, 14/4, 30/5, 17/7, 24/8, 13/9) and five times during 1992/93 (1/11, 14/4, 1/6, 8/7, 4/9), known numbers of males and females (usually 40 pairs) were collected soon after emergence from artificially infested pear branches and introduced into four of the enclosed branches (10 pairs per branch). For the overwintered adults much higher numbers were collected (331 pairs in 1991 and 175 pairs in 1992) because mortality during winter is usually very high. At regular intervals (usually 7 days in winter and 5 days in spring, summer and autumn), adults were carefully removed from the screen cage with a small glass vial by lightly tapping the branch, and eggs deposited on the branches were counted. Live adults were transferred to another set of four branches where they continued ovipositing. The same procedure was followed until adults died.

*Calculation of demographic parameters.* For each cohort of adults, the proportion of the cohort surviving at the beginning of each sampling interval and the number of eggs produced per female during the sampling interval were estimated. From the above estimates the following demographic parameters were calculated: 1) Expectation of life at emergence (mean longevity of the cohort), 2) Net fecundity at emergence, 3) Gross fecundity (the total number of eggs laid by a female that lived to the last day of life of the cohort), 4) Mean age of reproduction, i.e. the period elapsing from the emergence of the females to the average time the eggs were laid. Because gross fecundity is the sum of the daily number of eggs laid by a female that lived the longest time possible, it expresses mean fecundity of the cohort if mortality occurred only at the end of the life period. For the overwintered females life expectancy and net fecundity were calculated per initial female as well as per female alive at the beginning of the oviposition period. In these cases mortality during the hibernation period was excluded from the calculations. The formulae used to calculate the above parameters and their variances are given in the literature (Carey,

1993). The comparison of means was made by the Duncan's multiple range test.

## Results

*Winter form.* Table 1 gives the mean longevity, the net fecundity at emergence and the gross fecundity of adults of the winter form that emerged on October 31, 1991 and November 1, 1992. Male longevity was shorter than that of females in both years. Mean longevity of both males and females was relatively low, when compared to the maximum life period of these adults (up to the end of April in both years), indicating that heavy mortality occurred during the winter period. Apparently due to this, net fecundity at emergence was relatively very low in both years, although in 1992/93 it was almost twice that of 1991/92. For the same reason, the calculated variances for net fecundity were particularly high. Gross fecundity, in both years, was much higher than net fecundity (ratio 28.9 for 1991/92 and 9.8 for 1992/93).

Table 2 provides additional data for the overwintered females. It gives the proportion of the female population that survived hibernation and was alive at the beginning of the oviposition period (1 February in 1991/92 and 4 February in 1992/93). It also gives the life expectancy and net fecundity of those females. The results showed that a relatively small fraction of the emerged females survived until egg laying started. Life expectancy in both years was approximately one month. Net fecundity was in both years much higher than the corresponding estimate of net fecundity at emergence because the high mortality during the hibernation period was excluded from the calculations.

*Summer form.* The mean and variance of most demographic parameters is determined, to a great extent, by the distribution of mortality with age during the life period of the cohort which is usually described by the survivorship curves. Figure 1 shows the survivorship curves of the females that emerged on 30/5/92, 17/7/92 and 24/8/92; the type of the survivorship curves of the other cohorts of the summer form adults were similar to the ones presented. Unlike the winter form females, the greatest proportion of the summer form females survived the short pre-oviposition period and mortality rates during the life period of the cohort were fairly constant.

Tables 3 and 4 give the mean longevity of males and females, mean age of reproduction of females, net

Table 1. Mean longevity (days) of males and females, net fecundity at emergence (eggs per female) and gross fecundity (eggs per female) of females emerged on October 31/1991 and November 1/1992

Date of emergence	Longevity ( $\bar{x} \pm SD$ )		Net fecundity ( $\bar{x} \pm SD$ )	Gross fecundity
	males	females		
31/10/91	55.5 $\pm$ 22.6	60.0 $\pm$ 30.3	24.06 $\pm$ 78.3	670.5
1/11/92	58.6 $\pm$ 25.0	71.2 $\pm$ 39.9	43.39 $\pm$ 108.5	423.6

Table 2. The fraction of the initial female population alive at the beginning of the oviposition period and their life expectancy (remaining life in days) and net fecundity (eggs per female)

Date of emergence	Surviving fraction	Life expectancy ( $\bar{x} \pm SD$ )	Net fecundity ( $\bar{x} \pm SD$ )
31/10/91	0.178	29.5 $\pm$ 20.1	135.0 $\pm$ 139.3
1/11/92	0.286	35.5 $\pm$ 26.1	151.9 $\pm$ 157.1

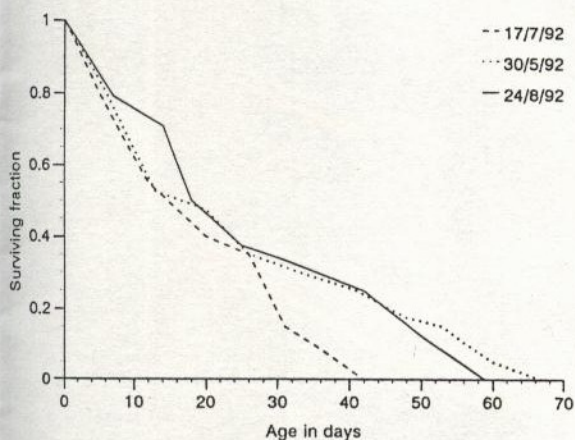


Figure 1. The surviving fraction at various ages of the females emerged on three dates (30/5, 17/7, 24/8) during 1992.

fecundity at emergence and gross fecundity of females of the summer form adults emerged on various dates during 1992 and 1993 respectively. In all cases, male longevity was shorter than that of female. Statistically significant differences (at the 0.05 level) were detected in 8 out of 9 cases. In both years, the changes in male and female longevity from spring to autumn showed a well defined trend. Longevity decreased from spring to summer and increased from summer to autumn. Because this is a gradual change of a parameter with great variability among individuals of the same cohort, as indicated by the high variances, statistical significance was not detected in all cases with the sample size used. The coefficient of variation for male longevity ranged from 50 (8/7/93) to 94.9% (4/9/93)

and for female longevity from 40.9 (1/6/93) to 83.5% (30/5/92).

The changes in net fecundity from spring to autumn followed a similar pattern as the one observed for longevity. The net fecundity of females that emerged in spring was very high. It was found to be relatively low in the females that emerged in late spring-early summer and very low in the females that emerged in summer. The net fecundity increased again in the females that emerged in late summer and oviposited in the autumn. The statistical comparisons between the net fecundity estimates of the cohorts in the various periods of the year confirmed the pattern described above. The coefficient of variation of net fecundity estimates ranged from 33.2 (1/6/93) to 83.1% (8/7/93). The changes in gross fecundity of the females that emerged on various dates during the season show the same trend as those of the net fecundity and longevity. The ratio of the gross fecundity to the net fecundity ranged from 1.48 (13/9/92) to 3.58 (8/7/93) with a mean value of 2.18.

The mean age of reproduction of females that emerged in the spring (14/4/92 and 14/4/93) was much shorter than the longevity of the same females (15.3 vs. 25.9 and 15.9 vs. 28.4). This relationship changes gradually. For the females that emerged in the summer (17/7/92, 8/7/93) the mean age of reproduction is approximately equal to mean longevity (17.2 vs. 17.4 and 16.1 vs. 14.3 respectively) while for females that emerged in the early autumn (13/9/92 and 4/9/93) the relationship approaches that observed in the spring.

Table 3. Mean longevity (days) of males and females net fecundity at emergence (eggs per female), gross fecundity (eggs per female) and mean age of reproduction (days) of females of the summer form emerged on various dates during 1992

Date of emergence	Longevity		Mean age of reproduction	Net fecundity (at emergence)	Gross fecundity
	males	females			
14/4/92	16.1 ab	25.9 b	15.3 a	343.2 d	618.5
30/5/92	15.4 ab	23.7 ab	16.5 a	67.7 a	143.8
17/7/92	11.5 a	17.4 a	17.2 a	46.5 a	152.4
24/8/92	18.2 b	24.4 ab	23.4 b	192.5 c	439.0
13/9/92	18.2 b	25.2 b	17.6 a	133.2 b	224.7

Means in columns followed by similar letter do not differ significantly at the 0.05 level.

Table 4. Mean longevity (days) of males and females, net fecundity at emergence (eggs per female), gross fecundity (eggs per female) and mean age of reproduction (in days) of females of the summer form emerged on various dates during 1993

Date of emergence	Longevity		Mean age of reproduction	Net fecundity (at emergence)	Gross fecundity
	males	females			
14/4/93	20.2 b	28.4 b	15.9 a	406.8 c	651.6
1/6/93	19.0 b	27.6 b	17.8 a	119.5 b	177.3
8/7/93	10.0 a	14.3 a	16.1 a	21.9 a	78.3
4/9/93	13.6 a	22.3 a	14.1 a	130.4 b	231.6

Means in columns followed by similar letter do not differ significantly at the 0.05 level.

## Discussion

*Winter form.* The results obtained in this study showed that the net fecundity of the overwintering females is rather low because only a small fraction of the females survived the long hibernation period and oviposited during February-March. The estimates of female longevity indicate that the average newborn female does not survive the hibernation period. In nature, net fecundity (at emergence) will likely be even lower than estimated in this study because the overwintering population of *C. pyri* is rather in a dispersive phase (Fye, 1983; Rieux et al., 1992; Horton et al., 1993), and mortality should be greater than in the field cages. However, females that survive and oviposit in February-March are capable of producing a relatively high number of eggs. This has been also confirmed by counts of mature oocytes in dissected females (Lyousoufi et al., 1988; Stratopoulou & Kapatos, 1995).

The great difference between gross fecundity and net fecundity at emergence reflects the observed distribution of mortality with age (heavy mortality rates particularly during the hibernation period) which has a significant ecological meaning. It suggests that substantial changes in the survival during this period between years can cause significant differences in net fecun-

dity, as observed in this study between 1991/92 and 1992/93, and subsequently in the infestation levels during the first infestation period (February-March), something which is very often observed in the field.

*Summer form.* The results showed that the females live longer than males and this is in agreement with observations on the sex ratio of the adult population in the field (Stratopoulou & Kapatos, 1995). Longevity of both males and females is shorter in the summer than it is in the spring and autumn.

The results indicated that the net fecundity of summer form females changes considerably throughout the season. Net fecundity of females emerging in the spring is very high, confirming that spring is the most favourable period for reproduction of pear psylla. Unfavourable environmental conditions during the summer reduce the reproductive potential of pear psylla females to very low levels. The conditions for reproduction of pear psylla become relatively favourable later in the autumn. These changes are not only due to different mortality rates but also to changes in the reproductive capacity of the females in the various periods of the year as it is indicated by the corresponding estimates of gross fecundity. Results of another parallel study (Stratopoulou & Kapatos, 1995) indicat-

ed low numbers of mature eggs in the ovaries of the females during the summer compared with other periods of the year, suggesting that ovarian development is suppressed during this period.

Changes in the reproductive potential of pear psylla females from spring to autumn could be attributed to a number of factors including host plant condition and temperature. The growth of the pear tree, as in most fruit trees, is fast in the spring, it almost stops in the summer and it resumes slightly after harvest in the late summer; water stress is considered one of the main causes of this (Raftopoulos, 1968). These changes are expected to have a significant effect on pear sucking insects, like *C. pyri* and, therefore, appear as one of the major causes for the changes in the reproductive potential of pear psylla from the spring to the autumn. Results from other studies (McMullen & Jong 1972; Fuog, 1984) support the above suggestion. It is also probable that high temperatures during the summer reduce the reproductive potential of pear psylla by suppressing the ovarian development as it was indicated on *C. pyricola*, a closely related species on the same host (McMullen & Jong, 1977).

The greatest differences between gross fecundity and net fecundity were observed in the summer when mortality rates were higher. The ratio of the two fecundity rates of the various cohorts fell within a narrow range (1.48-3.58) with a low mean value (2.18), i.e. gross fecundity was on the average twice as much as the net fecundity. This was because the pre-oviposition period of the females of the summer form is very short and mortality during this period is low and also because the survivorship curves of the summer form females indicated a rather uniform distribution of mortality with age. Therefore, it is reasonably assumed that variation in the mortality rates of the summer form females in relevant periods between years does not play a very significant role in the dynamics of the egg population.

The comparison of the mean age of reproduction with the mean longevity of the females indicated that during the spring more eggs are laid at the beginning rather than at the end of the life period of the cohort while during the summer it appears that eggs are laid rather uniformly during the life period of the cohort. This is also concluded by examining the age-specific fecundity schedules of the various cohorts (though not presented here). Probably longevity and mean age of reproduction are not equally affected by the changes of temperature or other ambient factors from spring to autumn.

The results obtained in this study are, generally, in agreement with previous data on the fecundity of pear psylla females under controlled conditions, although they are not directly comparable with them (Bonnemaison & Missonier, 1956). It is concluded that the main fluctuations of the egg population during the season observed in the field can be explained, to a certain extent, by the changes in the reproductive potential of pear psylla females and this conclusion is in agreement with opinions that have been expressed earlier (Atger, 1979; Broumas et al., 1989). It is possible, however, that other factors (e.g. predators) could also be partly responsible for the reduced number of eggs that is observed in the field during some periods of the year (e.g. summer).

The results indicate that control of the adult population in the winter (end January-beginning February), after the heavy mortality during hibernation has occurred, is justified because surviving females have a relatively high reproductive potential. This is further enhanced by the increased reproductive potential of the ensuing spring generation. Similar views, based on counts of mature oocytes in dissected females, have been expressed earlier (Lyoussofi et al., 1988). On the contrary, infestation levels during the summer are expected to be rather low not requiring control measures provided that the spring population of pear psylla has been suppressed.

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