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Effect of Different Temperatures and Host Plants on the Biology of the Long-Tailed Mealy Bug *Pseudococcus longispinus* (Targioni and Tozzetti) (Homoptera: Pseudococcidae)

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Abstract. Experiments were done to determine the effects of different temperature levels and three host plants namely, *Cucurbita moschata* (butternut squashes), *Solanum tuberosum* var. Desiree (red potato), and *Solanum tuberosum* var. Cara (white potato) on the biology of mealy bug *Pseudococcus longispinus* (Targioni and Tozzetti). It was found that the temperature had a significant effect on the development period of both male and female mealy bugs. For males the period decreased with increasing temperatures up to 28 °C, but increased thereafter and host plant had no effect, except at 24 °C. All the aspects of females including total pre-adult, prelarviposition, larviposition period, life span, fecundity and sex ratio were affected by the fluctuating temperatures, but host plant produced no effect on fecundity and sex ratio.

Keywords: mealy bug, temperature, host plants, life span, sex ratio

Introduction

Long-tailed mealy bug *Pseudococcus longispinus* (Targioni and Tozzetti) is mainly of tropical and subtropical origin and in glasshouses in temperate zone and many of them have become established as pests. It is found in the Mediterranean Basin, Africa, Southern Asia, Far East, Australia, New Zealand, Pacific Islands, USA, Central and South America (CIE, 1958). They attack a wide range of plants including fruits, vegetables and ornamentals and can cause severe damage to leaves, bark, branches, fruit and roots. They may occur under bark and cause some kinds of galls (Copland *et al*., 1985; Miller and Kosztarab, 1979). The very broad host range of mealy bugs in part explains their success. As sap feeders, they have the potential to be vectors of various viral diseases (Campbell, 1983; Harris, 1981). Some species are known to inject potent phytotoxins during feeding (Lema and Herren, 1985). Their direct damage takes the form of distortion, stunting and yellowing of foliage, early dropping of the flowers and fruits, sometimes followed by defoliation. Indirectly, their copious secretion of honeydew promotes the growth of sooty moulds which can detract from the aesthetic and economic value of these plants (Hattingh, 1993; Copland *et al*., 1985; Pritchard, 1949).

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Clausen (1915) studied the life history of *P. longispinus*, and was experienced considerable difficulty in measuring the rate of larviposition due to the disturbing effect it had upon the female. He observed that the young remain clustered under the body of the parent for one or more days after birth. The periods of time required for different stages were variable. Mating took place largely during the third instar and larviposition began within 10 to 15 days after the third moult. James (1937) studied the pre-adult stages of *P. longispinus* including the egg. He found three nymphal instars in the female and four in the male. The sexes were indistinguishable externally in the first instar but sexual dimorphism was apparent in the second instar. Panis (1969), who described *P. longispinus* as a viviparous species, showed that light, gravity and host plant quality had a great effect on adult orientation and distribution on plant leaves as well as on its sex ratio; mating was obligatory for the production of eggs and the development of the ovaries. Males were capable of several matings. El-Minshawy *et al*. (1974) studied the biology of *P. longispinus* at different stages. They found that the duration of all pre-adult stages was greatly affected by temperature.

Mealy bug is posing a serious threat to the plants, fruits, vegetables and ornamentals in the field and in glass houses. The long tailed mealy bug has a thick layered wax on its body which makes hard to control it chemically. Very little information is available regarding longtailed mealy bugs bionomics. El-Minshawy (1974) found that the duration of all pre adult stages were greatly effected by temperature therefore different temperature regimes were included in the studies.

The extended development period at 32 °C was a strange response of long tailed mealy bug to the temperature. Dr. Panis (1969) also observed the same phenomenon in some other mealy bug species as well. The reason for this behaviour in this mealy bug is yet not clear.

The host plants and temperatures used in this study are normally encountered by long tailed mealy bug in the fields and in the glasshouses. The number of its host plants is increasing gradually. The temperature has some effect on its life cycle but the host plants have a little role. This means this mealy bug can adapt to any host plant easily. This type of information was not available previously especially when similar types of studies were being conducted on its potential host i.e. brown lacewing. In this study, the effect of temperature and three different host plants on the biology of long-tailed mealy bug has been investigated.

Materials and Methods

The experiments were done in the Department of Environment, Wye College, University of London. The effect of four different temperatures, i.e. 20 °C, 24 °C, 28 °C and 32°C and three different host plants, i.e. *Cucurbita moschata* (butternut squashes), *Solanum tuberosum* var. Desiree (red potato), and *Solanum tuberosum* var. Cara (white potato), on the biology of long-tailed mealy bugs was studied. The temperatures for the studies were achieved in controlled temperature incubators. Five reproducing females were released on each host plant for 24 h. The crawlers laid by these females (F_1 generation) were allowed to develop and complete their life cycle on the host plants. For biological studies, five newly emerged 4^{th}-instar females (F_1) from each of these host plants were then isolated and confined with males for fertilisation. These fertilised females were then released singly on each respective host plant. Each female represented one replicate (five replicates). The crawlers laid by the females (F_2 generation) were counted and their positions were noted after settling down. Studies were conducted for development of different stages, pre-larviposition period, larviposition period, fecundity, female longevity and life-span. The observations were taken after every 24 h. For sex ratio determination, another ten such females were released on each host. Their progeny was raised until the determination of sexes.

Data obtained on the development of different stages, fecundity, survival and total life-span, were statistically analysed by using one-way ANOVA and means were compared using Fisher's test at 5% level of significance. The data for sex ratio were pooled separately into males and females on emergence at each temperature and on each host for Chi squared test. The LSD values were also calculated.

Results and Discussion

Effect of temperature on the development of the male *P. longispinus*. Temperature had a pronounced effect on the development of males. The first-instar periods were significantly different from each other at all four temperatures (Table 1) with greatest duration at 20 °C and least at 32 °C. Host plants have no significant effect on the duration at any of the temperatures although development appeared shorter on *C. moschata* at all temperatures (Table 1).

Temperature had a significant effect on the second-instar male. A decrease in the duration of this instar was observed with increasing temperature from 20 °C to 28 °C except on butternut squash where the minimum period was observed at 24 °C ($P < 0.05$, Table 2). The longest duration was at 32 °C. The effect of host is also evident in this instar. On butternut squashes the stadia were significantly shorter than on the other two hosts at 20 °C and 24 °C (Table 2). No significant host effect was found at 32 °C (Table 2).

The third-instar males were also affected by the temperature. The development periods decreased on all the hosts with increase in temperature up to 28 °C (Table 3), but increased again at 32 °C. The host plants had no effect on third-instar males except on butternuts at 28 °C where their development period was significantly shorter than on the other two hosts ($P < 0.05$, Table 3).

The development period of fourth-instar males was longest at 20 °C and shortest at 28 °C ($P < 0.05$, Table 4). It increased again at 32 °C ($P < 0.05$). The host plants had no effect on this stage at any of the temperature levels, except at 24 °C where the fourth-instar on butternuts was significantly shorter than that on the white potato (Table 4).

Overall temperature had a significant effect on the total pre-adult period of the male. The total pre-adult periods were significantly different from each other at all temperatures (P < 0.05, Table 5). The period decreased with increasing temperatures up to 28 °C, but increased thereafter. The host effect was non significant (P > 0.05, Table 5) except at 24 °C (P < 0.05, Table 5).

Effect of temperature on the development of the female *P. longispinus*. Temperature had a pronounced effect on the first-instar female. There was a significant decrease in the first-instar periods with increasing temperature which was longest at 20 °C (Table 6). The effect of host plant was also quite evident at 20 °C, 28 °C, and 32 °C. The stadia were significantly shorter on butternut squashes as compared to either potato cv at these temperatures (P < 0.05, Table 6). The effect of host was also noted at 28 °C on *S. tuberosum* var. 'Desiree' where the developmental period was significantly longer than the other two hosts (P < 0.05, Table 6).

The second-instar periods gradually decreased with the rising temperature up to 28 °C. There was no significant

Table 1. Effect of four different temperatures and three host plants on the development of first-instar of male *P. longispinus* (Mean development periods in day's ± S.E.)

Host plants	20 °C	24 °C	28 °C	32 °C	LSD 5% value	P 5% value
C. moschata Butternut	14.92 ± 0.16 aA n = 170	13.42 ± 0.15 aB n = 255	11.35 ± 0.20 aC n = 230	10.11 ± 0.14 aD n = 31	0.496	< 0.05
S. tuberosum var. Desiree	15.45 ± 0.22 aA n = 142	13.45 ± 0.17 aB n = 246	11.56 ± 0.17 aC n = 204	10.38 ± 0.21 aD n = 30	0.575	< 0.05
S. tuberosum var. Cara	15.41 ± 0.21 aA n = 137	13.62 ± 0.13 aB n = 244	11.63 ± 0.13 aC n = 202	10.30 ± 0.14 aD n = 26	0.468	< 0.05
LSD5% value P 5% value	0.612 > 0.05	0.471 > 0.05	0.521 > 0.05	0.506 > 0.05		

Means in columns followed by same lowercase letters are not significantly different at P ≤ 0.05 (ANOVA one-way, LSD 5% value, Fisher's test); Means in rows followed by same uppercase letters are not significantly different at P ≤ 0.05 (ANOVA one-way, LSD 5% value, Fisher's test); n represents the total number of individuals.

Table 2. Effect of four different temperatures and three host plants on the development of second-instar of male *P. longispinus* (Mean development periods in day's ± S.E.)

Host plants	20 °C	24 °C	28 °C	32 °C	LSD 5% value	P 5% value
C. moschata Butternut	13.09 ± 0.22 bB n = 170	8.21 ± 0.21 bD n = 255	9.43 ± 0.15 aC n = 230	15.27 ± 0.17 aA n = 31	0.572	< 0.05
S. tuberosum var. Desiree	14.33 ± 0.19 aB n = 142	9.10 ± 0.16 aC n = 246	8.90 ± 0.12 bD n = 204	15.19 ± 0.23 aA n = 30	0.533	< 0.05
S. tuberosum var. Cara	14.27 ± 0.18 aB n = 137	9.31 ± 0.17 aC n = 244	8.37 ± 0.16 cD n = 202	15.38 ± 0.18 aA n = 26	0.507	< 0.05
LSD 5% value P 5% value	0.699 > 0.05	0.566 > 0.05	0.428 > 0.05	0.602 > 0.05		

Means in columns followed by same lowercase letters are not significantly different at P ≤ 0.05 (ANOVA one-way, LSD 5% value, Fisher's test); Means in rows followed by same uppercase letters are not significantly different at P ≤ 0.05 (ANOVA one-way, LSD 5% value, Fisher's test); n represents the total number of individuals.

difference in stadia on any host at 28 °C and 32 °C (P > 0.05, Table 7). The development period of second-instar was significantly shorter on butternut squashes than the other two hosts at 20 °C. The period observed on *S. tuberosum* var. 'Cara' was significantly longer than that of *C. moschata* at 24 °C (P < 0.05, Table 7).

The development period of third-instar females decreased with temperature rising from 20 °C to 24 °C but increased at 28 °C and 32 °C (Table 8). No effect of hosts was found at 20 °C and 24 °C (P > 0.05, Table 8). On butternut the duration of third-instar was significantly shorter than on the other two hosts at 28 °C (P < 0.05, Table 8).

Total pre-adult development period of females was significantly reduced with increasing temperatures from 20 °C to 28 °C on all hosts. The total development period started increasing after 28 °C on all the host plants (P < 0.05, Table 9). The host effect was pronounced at 20 °C and 28 °C. At 20 °C and 28 °C, the total development period was significantly shorter on *C. moschata* as compared with the other two hosts (P < 0.05, Table 9).

Table 3. Effect of four different temperatures and three host plants on the development of third-instar of male *P. longispinus* (Mean development periods in day's ± S.E.)

Host plants	20 °C	24 °C	28 °C	32 °C	LSD 5% value	P 5% value
C. moschata Butternut	10.35 ± 0.18 aA n = 170	6.32 ± 0.23 aB n = 255	4.39 ± 0.14 bD n = 230	5.12 ± 0.18 aC n = 31	0.554	< 0.05
S. tuberosum var. Desiree	10.49 ± 0.13 aA n = 142	6.55 ± 0.15 aB n = 246	4.98 ± 0.10 aC n = 204	5.32 ± 0.15 aC n = 30	0.408	< 0.05
S. tuberosum var. Cara	10.82 ± 0.24 aA n = 137	6.83 ± 0.23 aB n = 244	5.00 ± 0.05 aC n = 202	5.26 ± 0.12 aC n = 26	0.044	< 0.05
LSD 5% value P 5% value	0.580 > 0.05	0.630 > 0.05	0.326 > 0.05	0.473 > 0.05		

Means in columns followed by same lowercase letters are not significantly different at P ≤ 0.05 (ANOVA one-way, LSD 5% value, Fisher's test); Means in rows followed by same uppercase letters are not significantly different at P ≤ 0.05 (ANOVA one-way, LSD 5% value, Fisher's test); n represents the total number of individuals.

Table 4. Effect of four different temperatures and three host plants on the development of fourth-instar of male *P. longispinus* (Mean development periods in day's ± S.E.)

Host plants	20 °C	24 °C	28 °C	32 °C	LSD 5% value	P 5% value
C. moschata Butternut	5.38 ± 0.15 aA n = 170	4.49 ± 0.13 bB n = 255	3.49 ± 0.17 aC n = 230	5.18 ± 0.14 aA n = 31	0.441	< 0.05
S. tuberosum var. Desiree	5.32 ± 0.14 aA n = 142	4.83 ± 0.1 aB n = 246	3.42 ± 0.13 aC n = 204	5.30 ± 0.08 aA n = 30	0.340	< 0.05
S. tuberosum var. Cara	5.60 ± 0.11 aA n = 137	5.08 ± 0.13 aB n = 244	3.45 ± 0.06 aC n = 202	5.20 ± 0.05 aB n = 26	0.278	< 0.05
LSD 5% value P 5% value	0.406 > 0.05	0.360 > 0.05	0.397 > 0.05	0.306 > 0.05		

Means in columns followed by same lowercase letters are not significantly different at P ≤ 0.05 (ANOVA one-way, LSD 5% value, Fisher's test); Means in rows followed by same uppercase letters are not significantly different at P ≤ 0.05 (ANOVA one-way, LSD 5% value, Fisher's test); n represents the total number of individuals.

Effect of temperature on the prelarviposition period of *P. longispinus*. Temperature had a significant effect on the prelarviposition period. Reductions in periods were observed with increasing temperature, with the maximum at 20 °C and minimum at 32 °C (P < 0.05, Table 10). No host effect was found at 20 °C and 32 °C. The period was significantly longer on *S. tuberosum* var. Desiree at 24 °C (P < 0.05) and shorter on *C. moschata* at 28 °C (P < 0.05, Table 10).

Effect of temperature on the larviposition period of *P. longispinus*. The periods were maximum at 20 °C on all hosts (Table 11) and were reduced until 28 °C with a drastic reduction at 32 °C (P < 0.05, Table 11). The effect of hosts was pronounced at all temperatures except 24 °C. The larviposition period was significantly shorter on *C. moschata* as compared to the other two hosts at 20 °C but was the longest at 32 °C (P < 0.05, Table 11).

Effect of temperature on the life-span of female *P. longispinus*. Increase in temperature exerted a significant effect on the total life-span of female *P. longispinus*. The life-span was maximum at 20 °C, becoming reduced with increasing temperatures until 32 °C (P < 0.05, Table 12). The period was shorter on

Table 5. Effect of four different temperatures and three host plants on the total pre-adult period of male *P. longispinus* (Mean pre-adult periods in day's ± S.E.)

Host plants	20 °C	24 °C	28 °C	32 °C	LSD 5% value	P 5% value
C. moschata Butternut	43.74 ± 0.68 aA n = 170	32.44 ± 0.57 bC n = 255	28.66 ± 0.60 aD n = 230	35.68 ± 0.31 aB n = 31	1.558	< 0.05
S. tuberosum var. Desiree	45.59 ± 0.67 aA n = 142	33.93 ± 0.4 aC n = 246	28.86 ± 0.15 aD n = 204	36.19 ± 0.31 aB n = 30	1.305	< 0.05
S. tuberosum var. Cara	46.10 ± 0.67 aA n = 137	34.84 ± 0.60 aC n = 244	28.45 ± 0.30 aD n = 202	36.14 ± 0.48 aB n = 26	1.609	< 0.05
LSD 5% value	2.085	1.665	0.988	1.163		
P 5% value	> 0.05	> 0.05	> 0.05	> 0.05		

Means in columns followed by same lowercase letters are not significantly different at P ≤ 0.05 (ANOVA one-way, LSD 5% value, Fisher's test); Means in rows followed by same uppercase letters are not significantly different at P ≤ 0.05 (ANOVA one-way, LSD 5% value, Fisher's test); n represents the total number of individuals.

Table 6. Effect of four different temperatures and three host plants on the development of first-instar of female *P. longispinus* (Mean development periods in day's ± S.E.)

Host plants	20 °C	24 °C	28 °C	32 °C	LSD 5% value	P 5% value
C. moschata Butternut	18.38 ± 0.05 bA n = 305	14.30 ± 0.21 aB n = 365	13.33 ± 0.17 bC n = 240	11.28 ± 0.17 bD n = 37	0.483	< 0.05
S. tuberosum var. Desiree	22.26 ± 0.16 aA n = 261	14.36 ± 0.27 aB n = 305	13.95 ± 0.08 aB n = 118	11.93 ± 0.19 aC n = 36	0.558	< 0.05
S. tuberosum var. Cara	22.32 ± 0.21 aA n = 260	14.59 ± 0.12 aB n = 301	13.55 ± 0.11 bC n = 224	11.96 ± 0.06 aD n = 32	0.412	< 0.05
LSD 5% value	0.481	0.639	0.392	0.461		
P 5% value	> 0.05	> 0.05	> 0.05	> 0.05		

Means in columns followed by same lowercase letters are not significantly different at P ≤ 0.05 (ANOVA one-way, LSD 5% value, Fisher's test); Means in rows followed by same uppercase letters are not significantly different at P ≤ 0.05 (ANOVA one-way, LSD 5% value, Fisher's test); n represents the total number of individuals.

C. moschata as compared to other hosts at all the temperatures except 32 °C, where the reverse was the case (Table 12).

Effect of temperature on fecundity. No significant effect of temperature on the number of crawlers produced was found at 20, 24 and 28 °C. However, the number of crawlers was very significantly reduced at 32 °C on all the hosts ($P < 0.05$, Table 13). There was no host effect on the fecundity at any temperature ($P < 0.05$, Table 13).

Effect of temperature on the sex ratio. An effect of temperature on the sex ratio was observed, with the proportion of females greatest at 20 °C and least at 28 °C, increasing again at 32 °C on all hosts ($P < 0.05$, Table 14). The observed sex ratios were significantly different from the expected at 20 and 24 °C on all the hosts ($P < 0.05$, Table 14). No significant difference between the observed and expected sex ratio was observed at 28 °C and 32 °C. There was no apparent host plant effect on the sex ratio at any temperature.

A complete biological knowledge of a pest is the pre-requisite for its successful biological control. Very little information is available regarding long-tailed mealy bug's bionomics. Flanders (1940) concluded

Table 7. Effect of four different temperatures and three host plants on the development of second-instar of female *P. longispinus* (Mean development periods in day's ± S.E.)

Host plants	20 °C	24 °C	28 °C	32 °C	LSD 5% value	P 5% value
C. moschata Butternut	13.98 ± 0.10 bA n = 305	10.19 ± 0.14 bB n = 365	9.55 ± 0.14 aC n = 240	10.03 ± 0.17 aB n = 37	0.472	< 0.05
S. tuberosum var. Desiree	16.28 ± 0.19 aA n = 261	10.53 ± 0.35 B n = 305	9.66 ± 0.06 aC n = 118	9.55 ± 0.19 aC n = 36	0.610	< 0.05
S. tuberosum var. Cara	16.71 ± 0.48 aA n = 260	11.35 ± 0.29 aB n = 301	9.78 ± 0.13 aC n = 224	9.65 ± 0.06 aC n = 32	0.854	< 0.05
LSD 5% value	0.931	0.827	0.357	0.432		
P 5% value	> 0.05	> 0.05	> 0.05	> 0.05		

Means in columns followed by same lowercase letters are not significantly different at $P \leq 0.05$ (ANOVA one-way, LSD 5% value, Fisher's test); Means in rows followed by same uppercase letters are not significantly different at $P \leq 0.05$ (ANOVA one-way, LSD 5% value, Fisher's test); n represents the total number of individuals.

Table 8. Effect of four different temperatures and three host plants on the development of third-instar of female *P. longispinus* (Mean development periods in day's ± S.E.)

Host plants	20 °C	24 °C	28 °C	32 °C	LSD 5% value	P 5% value
C. moschata Butternut	5.19 ± 0.10 aB n = 305	4.31 ± 0.14 aC n = 365	4.51 ± 0.12 bC n = 240	11.91 ± 0.18 aA n = 37	0.409	< 0.05
S. tuberosum var. Desiree	5.43 ± 0.22 aB n = 261	4.20 ± 0.15 aC n = 305	5.66 ± 0.10 aB n = 118	11.22 ± 0.16 bA n = 36	0.489	< 0.05
S. tuberosum var. Cara	5.43 ± 0.23 aB n = 260	4.95 ± 0.27 aC n = 301	5.54 ± 0.08 aB n = 224	11.30 ± 0.10 bA n = 32	0.569	< 0.05
LSD 5% value	0.591	0.793	0.310	0.471		
P 5% value	> 0.05	> 0.05	> 0.05	> 0.05		

Means in columns followed by same lowercase letters are not significantly different at $P \leq 0.05$ (ANOVA one-way, LSD 5% value, Fisher's test); Means in rows followed by same uppercase letters are not significantly different at $P \leq 0.05$ (ANOVA one-way, LSD 5% value, Fisher's test); n represents the total number of individuals.

that long-tailed mealy bug is native to Australia. El-Minshawy *et al*. (1974) and James (1937), had studied the biology of its different stages. In Auckland, the long-tailed mealy bug has three discrete generations on grapevines in a year.

Studies carried out in Russia by Oganesyan and Babayan (1979) showed that, the host, temperature and humidity had a marked effect on egg viability and duration of embryonic development of *Pseudococcus comstocki* (Kuw.). Considering the duration of the pre-adult stages, the data obtained revealed that all the developmental stages were significantly affected by temperature. A similar relationship of temperature and the pre-adult development periods of *P. longispinus* in different instars were also observed by Clausen (1915) and El-Minshawy *et al*. (1974).

The pre-adult development duration decreased with the increase in temperature up to 28 °C but started increasing except in crawlers after this temperature. Our findings are in accordance with El-Minshawy *et al*. (1974), who observed that the development of *P. longispinus* was extended at higher temperatures. The fecundity was

Table 9. Effect of four different temperatures and three host plants on the total pre-adult period of female *P. longispinus* (Mean pre-adult periods in day's ± S.E.)

Host plants	20 °C	24 °C	28 °C	32 °C	LSD 5% value	P 5% value
C. moschata Butternut	37.55 ± 0.21 bA n = 305	28.80 ± 0.42 bC n = 365	27.41 ± 0.43 bD n = 240	33.22 ± 0.26 aB n = 37	1.036	< 0.05
S. tuberosum var. Desiree	43.97 ± 0.56 aA n = 261	29.09 ± 0.8 abC n = 305	29.29 ± 0.07 aB n = 118	30.70 ± 0.39 bB n = 36	1.535	< 0.05
S. tuberosum var. Cara	44.46 ± 0.85 aA n = 260	30.89 ± 0.65 aC n = 301	28.87 ± 0.29 aD n = 224	32.91 ± 0.17 aB n = 32	1.685	< 0.05
LSD 5% value	1.854	1.97	0.935	0.880		
P 5% value	> 0.05	> 0.05	> 0.05	> 0.05		

Means in columns followed by same lowercase letters are not significantly different at P ≤ 0.05 (ANOVA one-way, LSD 5% value, Fisher's test); Means in rows followed by same uppercase letters are not significantly different at P ≤ 0.05 (ANOVA one-way, LSD 5% value, Fisher's test); n represents the total number of individuals.

Table 10. Effect of four different temperatures and three host plants on the prelarviposition period of *P. longispinus* (Mean prelarviposition periods in day's ± S.E.)

Host plants	20 °C	24 °C	28 °C	32 °C	LSD 5% value	P 5% value
C. moschata Butternut	26.16 ± 0.27 aA n = 10	23.26 ± 0.68 bB n = 10	22.11 ± 0.05 cC n = 10	10.26 ± 0.11 aD n = 10	1.116	< 0.05
S. tuberosum var. Desiree	26.30 ± 0.29 aA n = 10	24.98 ± 0.29 aB n = 10	22.93 ± 0.26 bC n = 10	09.94 ± 0.22 aD n = 10	0.803	< 0.05
S. tuberosum var. Cara	26.38 ± 0.31 aA n = 10	24.30 ± 0.3 abB n = 10	23.98 ± 0.3 abB n = 10	10.44 ± 0.12 aC n = 10	0.767	< 0.05
LSD 5% value	0.890	1.412	0.686	0.487		
P 5% value	> 0.05	> 0.05	> 0.05	> 0.05		

Means in columns followed by same lowercase letters are not significantly different at P ≤ 0.05 (ANOVA one-way, LSD 5% value, Fisher's test); Means in rows followed by same uppercase letters are not significantly different at P ≤ 0.05 (ANOVA one-way, LSD 5% value, Fisher's test); n represents the total number of individuals.

also greatly reduced at higher temperatures. The pre-larviposition, larviposition periods and adult longevity of the female were also significantly affected by temperature variations and were longer at lower temperatures and decreased with the increasing temperature. Wang *et al*. (1997) and Asante *et al*. (1991) observed similar phenomena in *Eriosoma lanigerum* (Hausmann) (Homoptera: Aphididae) and *Aphis nasturtii* Kaltenbach, (Homoptera: Aphididae), with the duration of the life-span of the female being extended at low temperatures. Oganesyan and Babayan (1979) observed a similar effect of low winter temperature on the development and population density of the first generation of *P. comstocki*.

The progeny reared at different temperatures showed that, temperature had a significant effect on the sex ratio, with a bias towards females at all tested temperatures except at 28 °C where the reverse occurred as was also observed by El-Minshawy *et al*. (1974). The reason for this deviation is unknown. In contrast to observations by Panis (1969), there was no significant effect of the host plants on sex ratio; however temperature does have an effect on the sex ratio.

Table 11. Effect of four different temperatures and three host plants on the larviposition period of *P. longispinus* (Mean prelarviposition periods in day's ± S.E.)

Host plants	20 °C	24 °C	28 °C	32 °C	LSD 5% value	P 5% value
C. moschata Butternut	33.92 ± 0.22 bA n = 10	26.03 ± 0.94 aB n = 10	20.89 ± 0.13 aC n = 10	12.05 ± 0.16 aD n = 10	1.475	< 0.05
S. tuberosum var. Desiree	35.78 ± 0.33 aA n = 10	26.93 ± 0.20 aB n = 10	20.11 ± 0.16 bC n = 10	10.52 ± 0.15 bD n = 10	0.208	< 0.05
S. tuberosum var. Cara	35.55 ± 0.40 aA n = 10	26.91 ± 0.44 aB n = 10	19.83 ± 0.22 bC n = 10	10.05 ± 0.14 cD n = 10	0.970	< 0.05
LSD 5% value	0.998	1.874	0.536	0.459		
P 5% value	> 0.05	> 0.05	> 0.05	> 0.05		

Means in columns followed by same lowercase letters are not significantly different at P ≤ 0.05 (ANOVA one-way, LSD 5% value, Fisher's test); Means in rows followed by same uppercase letters are not significantly different at P ≤ 0.05 (ANOVA one-way, LSD 5% value, Fisher's test); n represents the total number of individuals.

Table 12. Effect of four different temperatures and three host plants on the life-span of female *P. longispinus* (Mean in day's ± S.E.)

Host plants	20 °C	24 °C	28 °C	32 °C	LSD 5% value	P 5% value
C. moschata Butternut	97.63 ± 0.42 bA n = 10	78.09 ± 0.86 bB n = 10	70.41 ± 0.43 bC n = 10	55.53 ± 0.26 aD n = 10	1.603	< 0.05
S. tuberosum var. Desiree	106.05 ± 0.60 aA n = 10	81.00 ± 0.79 aB n = 10	72.33 ± 0.04 aC n = 10	51.20 ± 0.50 cD n = 10	1.642	< 0.05
S. tuberosum var. Cara	106.39 ± 0.89 aA n = 10	82.10 ± 0.55 aB n = 10	72.08 ± 0.35 aC n = 10	53.40 ± 0.16 bD n = 10	1.674	< 0.05
LSD 5% value	2.044	2.302	1.033	0.994		
P 5% value	> 0.05	> 0.05	> 0.05	> 0.05		

Means in columns followed by same lowercase letters are not significantly different at P ≤ 0.05 (ANOVA one-way, LSD 5% value, Fisher's test); Means in rows followed by same uppercase letters are not significantly different at P ≤ 0.05 (ANOVA one-way, LSD 5% value, Fisher's test); n represents the total number of individuals.

Table 13. Effect of four different temperatures and three host plants on the fecundity of *P. longispinus* (Mean fecundity ± S.E.)

Host plants	20 °C	24 °C	28 °C	32 °C	LSD 5% value	P 5% value
C. moschata Butternut	154.48 ± 10.1 aA n = 10	181.82 ± 26.7 aA n = 10	188.22 ± 34.0 aA n = 10	29.46 ± 4.2 aB n = 10	66.73	< 0.05
S. tuberosum var. Desiree	133.30 ± 13.8 aA n = 10	158.42 ± 32.5 aA n = 10	182.99 ± 12.9 aA n = 10	32.40 ± 5.3 cB n = 10	56.95	< 0.05
S. tuberosum var. Cara	133.30 ± 12.6 aA n = 10	158.46 ± 29.8 aA n = 10	180.54 ± 22.6 aA n = 10	28.20 ± 4.4 bB n = 10	59.46	< 0.05
LSD 5% value P 5% value	37.86 > 0.05	91.69 > 0.05	75.99 > 0.05	14.38 > 0.05		

Means in columns followed by same lowercase letters are not significantly different at P ≤ 0.05 (ANOVA one-way, LSD 5% value, Fisher's test); Means in rows followed by same uppercase letters are not significantly different at P ≤ 0.05 (ANOVA one-way, LSD 5% value, Fisher's test); n represents the total number of individuals.

Table 14. Effect of four different temperatures and three host plants on the sex of ratio of *P. longispinus*

Host plants	20 °C	24 °C	28 °C	32 °C
C. moschata Butternut	1 : 1.87 m = 330 f = 620 χ^2 = 88.53 P < 0.001	1 : 1.57 m = 460 f = 720 χ^2 = 60.21 P < 0.001	1 : 0.94 m = 510 f = 480 χ^2 = 0.91 P = 0.340	1 : 1.17 m = 60 f = 70 χ^2 = 0.77 P = 0.380
S. tuberosum var. Desiree	1 : 1.89 m = 280 f = 530 χ^2 = 77.16 P < 0.001	1 : 1.52 m = 400 f = 610 χ^2 = 43.66 P < 0.001	1 : 0.92 m = 490 f = 450 χ^2 = 1.702 P = 0.192	1 : 1.17 m = 60 f = 70 χ^2 = 0.77 P = 0.380
S. tuberosum var. Cara	1 : 1.93 m = 270 f = 520 χ^2 = 95.61 P < 0.001	1 : 1.46 m = 410 f = 600 χ^2 = 35.70 P < 0.001	1 : 0.92 m = 490 f = 450 χ^2 = 1.702 P = 0.192	1 : 1.2 m = 50 f = 60 χ^2 = 0.910 P = 0.340

χ^2 test used for the analysis of female sex ratio at 5% level of significance from 1:1 ratio; m represents total number of males and 'f' represents total number of females.

Johansson (1964) had stated that the quality of the food influences egg production in many phytophagous insects and thus the egg output may vary with plant species even if they belong to same genus. In the course of the present studies, no significant effect of host plant was observed on fecundity or sex ratio.

During the course of the present studies, the host plants seemed to have no effect on the lower threshold and thermal constants of the male *P. longispinus*, whereas they did have an effect on the lower threshold and thermal constant of the female. The female's lower threshold temperatures were lower than that of the male on all hosts, suggesting the female's greater tolerance and survival at low temperatures. It also suggested an early start of development in females. The host effect on T_1 was most pronounced in females on butternut squash. Lower threshold temperatures of both male and female were lowest on *C. moschata* as compared to the two *S. tuberosum* varieties.

Based upon these data, *P. longispinus* can best be produced in the laboratory on *C. moschata*, at between 20 °C to 28 °C.

References

Asante, S.K., Danthanarayana, W., Heatwole, H. 1991. Bionomics and population growth statistics of apterous virginoparae of wooly apple aphid, *Eriosoma lanigerum*, at constant temperatures. Entomologia *Experimentalis et Applicata*, **60:** 261-270.

Campbell, C.A.M. 1983. The assessment of mealybugs (Pseudococcidae) and other Homoptera on mature cocoa trees in Ghana. *Bulletin of Entomological Research*, **73:** 137-151.

CIE, 1958. *Distribution Maps of Pests*. Ser. A, Map No. 93. Commonwealth Institute of Entomology, London, UK.

Clausen, C.P. 1915. Mealy bugs of citrus trees. *Bulletin of Californian Agricultural Experimental Station*, **258:** 19-48.

Copland, M.J.W., Tingle, C.C.D., Saynor, M., Panis, A. 1985. Biology of glasshouse mealy bugs and their predators and parasitoids. pp. 82-86. In: *Biological Pest Control*: *The Glasshouse Experience*. N. W. Hussey and N. E. A. Scopes (eds.), 240 pp., Bland Ford Press, Poole, UK.

El-Minshawy, A.M., Karam, H.H., Sawaf, S.K.E. 1974. Biological studies on the longtailed mealybug *Pseudococcus longispinus* (Targ. and Tozzeti). *Bulletin of Entomological Society of Egypt*, **58:** 385-391.

Flanders, S.E. 1940. Biological control of the longtailed mealybug *Pseudococcus longispinus*. *Journal of Economic Entomology*, **33:** 754-759.

Gordon, H.T. 1984. Growth and development of insects. pp. 53-78. In: *Ecological Entomology*. Huffaker, C.B. & R. L. Rabb (eds.), 844 pp., John Wiley and Sons Publishers, New York, USA.

Harris, K.F. 1981. Arthropod and Nematode vectors of plant viruses. *Annual Review of Phytopathology*, **19:** 392-426.

Hattingh, V. 1993. Mealy bugs and cottony cushion scale on citrus in Southern Africa. *Citrus Journal*, **3:** 20-22.

James, H.C. 1937. On the pre-adult instars of *Pseudococcus longispinus* Targ, with special reference to characters of possible generic significance (Hem.). *Transactions of Royal Entomology Society of London*, **86:** 73-84.

Johansson, A.S. 1964. Feeding and nutrition in reproductive processes in insects. *Symposium of Royal Entomological Society of London*, **2:** 43-55.

Lema, K.M., Herren, H.R. 1985. The influence of constant temperature on population growth rate of cassava mealybug, *Phenococcus manihoti*. *Entomologia Experimentalis et Applicata*, **38:** 165-169.

Millar, D.R., Kosztarab, M. 1979. Recent advances in the study of scale insects. *Annual Review Entomology*, **24:** 1-27.

Oganesyan, S.B., Babayan, G.A. 1979. The influence of air temperature and humidity on the survival of egg and duration of embryonic development of the Comstock mealy bug. *Ekologiya*, **4:** 98-100.

Panis, A. 1969. Observations faunistiques et biologiques sur quelques Pseudococcidae (Homoptera: Coccidea) vivant dans le midi de la France. (Faunistical and biological observations on some Pseudococcidae living in southern France). *Annals Zoologie Ecology Animaux*, **1:** 211-244.

Pritchard, A.E. 1949. California greenhouse pests and their control. *Bulletin of California Agricultural Experimental Station*, **713:** 1-71.

Wang, K., Tsai, J.H., Harrison, N.A. 1997. Influence of temperature on development, survivorship, and reproduction of buckthorn aphid (Homoptera: Aphididae). *Annals Entomological Society of America*, **90:** 62-68.