

**THE ROLE OF *MATSUCOCCUS JOSEPHI* BODENHEIMER AND HARPAZ  
(HOMOPTERA: MATSUCOCCIDAE) AND OF DROUGHT  
IN THE EARLY STAGES OF NATURAL REGENERATION  
AFTER FIRE OF ALEPPO PINE FOREST IN ISRAEL<sup>1</sup>**

Zvi MENDEL<sup>1</sup>, FABIENNE ASSAEL<sup>1</sup>, NITZA SAPHIR<sup>2</sup>,

AMIRAM ZEHAVID<sup>2</sup> AND DAVID NESTEL<sup>1</sup>

<sup>1</sup>*department of Entomology, Agricultural Research Organization,  
The Volcani Center, Bet Dagan, Israel*

<sup>2</sup>*Forests Department, Keren Kayemet leIsrael, Eshat'ol, Israel*

**ABSTRACT**

Mortality of *Pinus halepensis* was investigated in Israel during the first years of natural regeneration after fire, with special emphasis on *Matsucoccus josephi* and on drought and competition. The investigations were conducted in a natural forest on Mt. Carmel, erroneously believed to be resistant to the scale, and in a plantation severely damaged by the scale at Horeshim in Samaria. *Matsucoccus josephi* was the dominant mortality agent, killing about 47% of the seedlings during the first four years after regeneration. Neither injury nor mortality due to the scale insect was recorded during the first year after regeneration, with maximum mortality occurring during the third and the fourth years. About 23% of the seedlings died due to drought and to interspecific and intraspecific competition; most of the mortality occurred during the first two years after regeneration. Mortality due to other arthropods was practically nil. It was shown that resistance to the scale of a regenerating population of *P. halepensis* on Mt. Carmel did not differ significantly from that at Horeshim, despite differences in the level of injury to the adult trees at each site. Seedling density in scale-infested plots, four years after natural seeding, is high enough to ensure stands development with the second growth possibly displaying less susceptibility to *M. josephi* than the present adult trees.

KEY WORDS: Coccoidea, Matsucoccidae, *Matsucoccus josephi*, *Pinus halepensis*, fire, regeneration, drought, Carmel, Israel.

**INTRODUCTION**

Fires and the pine bast scale *Matsucoccus josephi* Bodenheimer and Harpaz (Coccoidea: Matsucoccidae) have been two serious hazards in planted Aleppo pine (*Pinus halepensis*) in Israel since the 1940s. Fire usually favors the persistence of pine stands in many areas (see e.g.

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Mirov, 1967), Aleppo pine is a good pyrophyte; mass regeneration in different parts of the Mediterranean is usually observed after the first winter following fires (see e.g. Liacos, 1977; Karschon, 1973; Ne'eman et al., 1992; Trabaud et al., 1985).

Outbreaks of *Matsucoccus* spp. resulting in decline of pine forests are attributed to the activity of man, viz., introduction of the scale into new environments stocked by susceptible genotypes of the host tree or by related susceptible pines (Mendel, 1992; Mendel et al., 1994b). Aleppo pine is sensitive to even light infestation, which results in necrosis of the cortex and blockage of water transport (see e.g. Mendel and Liphshitz, 1988). Mendel et al. (1990b) suggested that the premature bark peeling followed by heavy resin exudation caused by *M. josephi* (Liphshitz and Mendel, 1989) accelerated the spread of fire in dense stands; canopy opening due to loss of needles encouraged the development of highly combustible ground cover.

In plantations of Aleppo pine in Israel, many of the seedlings that develop after fire or clear cutting next to mature stands are killed by *M. josephi* dispersed from nearby trees. So far no attempt was made to measure the mortality due to the scale and the possible involvement of other biotic agents.

The structure and dynamics of Aleppo pine in Israel are significantly affected by the interaction between fire and *M. josephi*. The objectives of this paper are: (1) to determine the major biotic agents that cause mortality during the first years of regeneration after fire; (2) to examine the rate and dynamics of seedling mortality caused by *M. josephi* as related to other mortality factors known to be operative here, viz., *Hylastes linearis* Erichson and *Pityophthorus pubescens* Marsham (Coleoptera: Scolytidae); and (3) to compare the role of the scale in natural regeneration in a relict forest, believed to be resistant to the scale, on Mt. Carmel and in an artificial plantation severely damaged by the scale, at Horeshim.

## MATERIALS AND METHODS

### Study sites

Two study sites were selected: (a) a natural, uneven-aged pine forest showing no significant injury symptoms due to *M. josephi*, on Mt. Carmel (32°46'N, 35°01'E), 320 m above sea level; (b) a 28–30-year-old plantation, heavily damaged by *M. josephi*, at Horeshim, on the western slopes of the Samarian Foothills (32°10'N, 34°59'E), 150 m above sea level. The work was conducted after massive fires had occurred at both sites in September 1989, which destroyed all pine trees over an area of about 500 ha and 100 ha, respectively, on Mt. Carmel and at Horeshim. Live pines at the Carmel site were at a distance of 800–1000 m from the burnt site, whereas at Horeshim adult pines were about 400 m to the south and a few trees 50–70 m to the north. We did not expect natural mass dispersal of crawlers of *M. josephi* by the prevailing westerly wind at both sites since the adult Aleppo pine trees at the sites were only lightly infested by the scale insect. Sampling and observations were conducted at the center of each burnt site. At Horeshim the slash was removed.

### Collection of data

Sampling plots (2 × 3 m or 3 × 3 m) were laid out at each study site in June 1990, after typical mass mortality of seedlings had occurred from drought and interspecific competition during the first months after the fire, as reported by Schiller (1979). Development of *M. josephi* on Aleppo

pine seedlings during the first months after germination is very poor (Z. Mendel, unpublished data). The treatments applied (A, B and C on Mt. Carmel and D at Horeshim) were as follows. Treatment A consisted of eight undisturbed plots, where relatively few pine seedlings occurred among dense growth of mainly perennials such as *Cistus* spp., *Calycotome villosa*, *Rhus coriaria* and *Pistacia lentiscus*. Treatment B was applied to eight plots, where relatively many seedlings occurred (see also Table 2) and the above-mentioned competing vegetation was constantly removed or cut back. Treatment C consisted of 10 plots treated like those of treatment B; in each plot 10 ovisacs of *M. josephi* from laboratory rearing (Mendel et al., 1990a) were attached to five seedlings (two seedlings with one ovisac, two seedlings with two ovisacs and a single seedling with four ovisacs) in May 1991. At Horeshim, treatment D consisted of 12 plots treated similarly to treatment C, but with less seedlings than in treatment C, the major competing plants being *Asparagus stipularis*, *Calycotome villosa* and *Rhus tripartita*. Pine seedlings were dominant in treatments B, C and D, whereas the competing vegetation was dominant in the plots of treatment A.

In each plot all seedlings were inspected at about 2-month intervals for infestation by the major insects affecting pine, viz., *M. josephi*, the pine processionary caterpillar *Thaumetopoea wilkinsoni* Tams (Lepidoptera: Thaumetopoidae), the pine shoot moth *Rhyacionia buoliana* (Schiffmüller) (Lepidoptera: Tortricidae), and the bark beetles *Hylastes linearis* Erichon and *Pityophthorus pubescens* Mars. Dead seedlings were removed for further examination and signs of injury from rodents or unidentified agents were recorded. The cause of death was determined according to the following criteria: (1) mortality of seedlings was attributed to drought if infestation by *M. josephi*, attack by borers and gnawing near the root collar were absent; (2) mortality caused by *M. josephi* was scored for seedlings which displayed colonization by the scale around the root collar and conspicuous resinosis; and (3) mortality due to other biotic agents, such as bark beetles or rodents, was determined from the specific symptoms brought about by these agents.

### Mortality from *M. josephi* and from drought and competition, as related to season

Mortality attributable to each agent during the four years was calculated separately for the dry season (summer, 16 June to 15 November) and the wet season (winter, 16 November to 15 June); the criteria used for determining the length of the season were the absence or availability of soil moisture (unpublished data). The annual amounts of rainfall at the nearest meteorological station to each site are given in Table 1.

TABLE 1  
Seasonal rainfall amount at the nearest meteorological stations  
(Dry season: June 1 to October 31; wet season: November 1 to May 31)

Year	Mt. Carmel		Horeshim	
	Dry season	Wet season	Dry season	Wet season
1989/90	55.0	685.0	48.0	511.8
1990/91	11.0	457.0	6.5	496.6
1991/92	17.2	1162.2	11.4	1227.7
1992/93	0	738.5	0	704.3

### Data analysis

Mean mortality rates (%) of seedlings for each treatment and year were analysed by ANOVA; angular transformations were applied to the plot means.

## RESULTS

### Mortality rates due to various agents

Table 2 lists seedling mortality due to the major phytophagous insects and other agents for each treatment and at each study site.

*M. josephi* was the dominant mortality agent in treatments B, C and D. Among the 2557 seedlings examined ca. 47% were killed by *M. josephi* during the first four years after regeneration. About 23% of the seedlings died from drought and/or interspecific and intraspecific competition. Other agents were responsible for the death of only very few seedlings. The contribution to the overall mortality by bark beetles was negligible (Table 2). Both *H. linearis* and *P. pubescens* occurred only on Mt. Carmel. Seedlings injured but not killed by *T. wilkinsoni* and *R. buoliana* were observed only at Horeshim.

TABLE 2

Major phytophagous insects and other possible mortality agents and their contribution to mortality of Aleppo pine seedlings on Mt. Carmel and at Horeshim forest, 1990–1993

Mortality agents	Natural forest (Mt. Carmel)			Plantation (Horeshim)	Total	
	Treatment A	Treatment B	Treatment C	Treatment D	Number	%
Seedlings at the beginning of the experiment						
Number	321	730	909	597	2557	100
Density/m <sup>2</sup>	15.3	30.4	27.2	8.3	–	
Mortality agents						
Drought and competition	251	96	62	171	580	22.7
<i>Matsucoccus josephi</i>	0	141	739	316	1196	46.8
<i>Hylastes linearis</i>	0	0	1	0	1	~0
<i>Pityophthorus pubescens</i>	0	1	2	0	3	0.1
Rodents or other mammals	4	5	6	2	17	0.7
Major nonlethal pests						
<i>Thaumtopoea wilkinsoni</i>	0	0	0	9	9	0.3
<i>Rhyacionia buoliana</i>	0	0	0	12	12	0.5
Seedlings four years after natural seeding						
Number	66	487	99	87	739	28.9
Density/m <sup>2</sup>	2.7	19.9	3.0	1.2	–	

Treatment A: undisturbed; treatment B: competing vegetation removed or cut back; treatments C and D: competing vegetation removed or cut back and artificial infestation with *M. josephi*.

**Effect of drought and competition on seedling mortality**

The annual rates of seedling mortality from drought and competition during the four years of the study are displayed in Fig. 1. On summing up these data, we found that in plots where the competing vegetation was constantly removed or cut back, viz., treatments B, C and D, total seedling mortality due to these factors during the four years was 12.7%, 6.5% and 28.8%, respectively. The highest total mortality (77.5%) due to drought was recorded on Mt. Carmel in undisturbed plots (treatment A), with the peak (47.6%) occurring in the second year after regeneration (1991). Also in treatment D the highest mortality occurred during the first two years after regeneration (Fig. 1). Mortality from drought and competition was highest in the wet season (winter) at Horeshim and in the dry season (summer) on Mt. Carmel (Fig. 2).

**Effect of *M. josephi* on seedling mortality**

In the spring and early summer of 1991 neither injury nor mortality due to *M. josephi* was recorded in the experimental plots and the surrounding areas. The first seedlings killed by the scale were noticed in late summer and fall of 1991. The annual rates of mortality caused by *M. josephi* are displayed in Fig. 1. The highest total mortality of seedlings due to the scale calculated from Fig. 1 was 82.1% and 55.7% in artificially infested plots on Mt. Carmel and Horeshim (treatments C and D), respectively. These mortality rates differed markedly from plots that were not infested artificially, being nil in treatment A and 14.7% in treatment B.

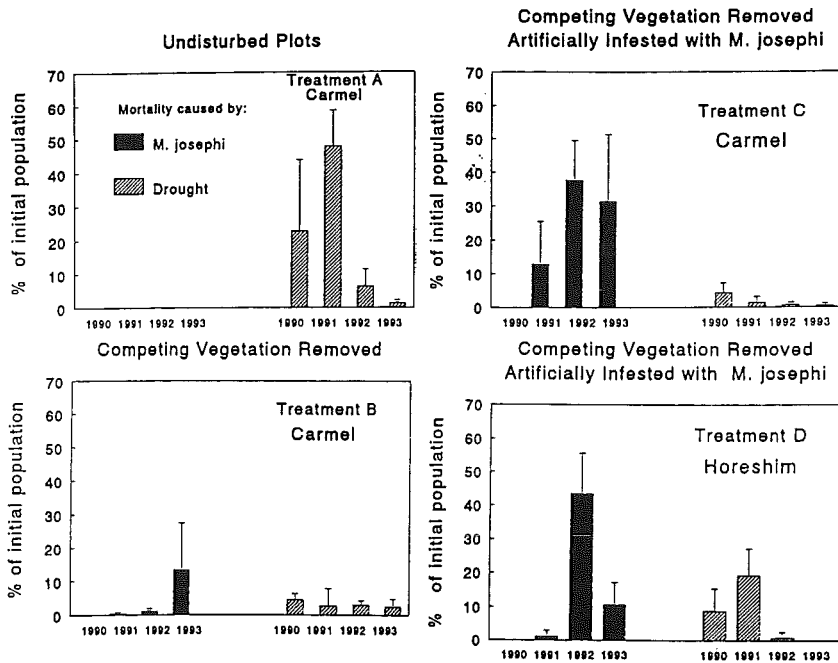


Fig. 1. Percentage mortality caused by *M. josephi* and drought to Aleppo pine seedlings in the first four years after natural seeding. A, Mt. Carmel, undisturbed; B, Mt. Carmel, competing vegetation constantly removed or cut back; C, Mt. Carmel, competing vegetation constantly removed or cut back and artificial infestation with *M. josephi*; D, Horeshim, similar to C. Bars indicate S.D. For more details see text.

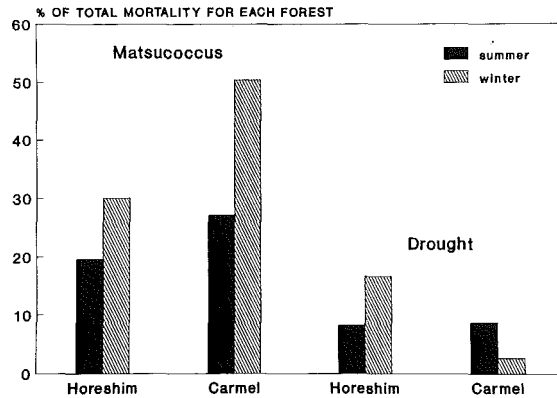


Fig. 2. Percent mortality of Aleppo pine seedlings after four years caused by *M. josephi* and drought as related to the season of the year. For further details see text.

Maximum mortality occurred during the third and fourth years after natural seeding (Fig. 1). Mortality due to *M. josephi* was much higher in the wet season (winter) both on Mt. Carmel and at Horeshim as compared to that in the dry season (summer) (Fig. 2).

#### Seedling survival during the first four years after regeneration

Seedling survival in the four treatments is displayed in Fig. 3. After four years, it was the lowest (8.4%) in treatment C (Mt. Carmel), where in some of the plots no seedlings survived; the mean number of seedlings per m<sup>2</sup> decreased during the four years from 27.2 to 3.0 (Table 2). The survival rate in the parallel treatment (D) at Horeshim was higher (14.8%) but did not differ significantly from treatment C; the mean number of seedlings per m<sup>2</sup> decreased from 8.3 to 1.2. In the undisturbed plots (treatment A) survival was 21.1%; the mean number of seedlings per m<sup>2</sup> decreased from 15.3 to 2.7. The highest survival (77.9%) was recorded in treatment B, with an only moderate decrease of seedling density from 30.4 to 19.9 per m<sup>2</sup>.

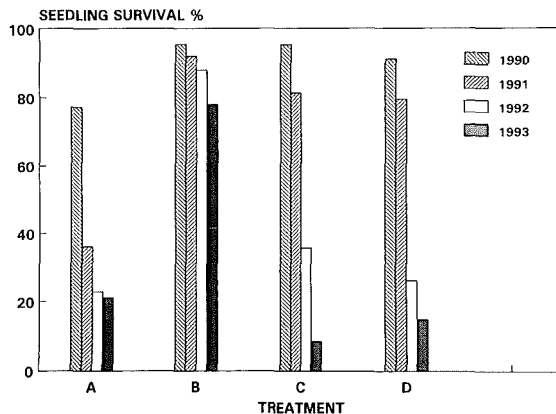


Fig. 3. Percentage survival of Aleppo pine seedlings from 1990 to 1993, according to treatment. For treatments see legend of Fig. 1.

## DISCUSSION

Our results may indicate that *M. josephi* is the dominant biotic mortality factor in natural regeneration of Aleppo pine in Israel. The impact of other biotic agents which attack seedlings during the first years, such as bark beetles, is practically nil. Both *H. linearis* and *P. pubescens* occur very rarely in local pine plantations. However, various species of the genus *Hylastes* are destructive agents of conifer seedlings (Chararas, 1962). Populations of *H. linearis* and *P. pubescens* were expected to increase after the fire, since both species successfully develop in the collar and roots of weakened and burnt trees (Halperin and Holzschuh, 1984; Mendel et al., 1985). The effect exerted by other major phytophagous insects of pine, viz., *T. wilkinsoni* and *R. buoliana*, was negligible at this early stage of stand development.

Drought, including competition for water between pine seedlings and other plants (mainly *Cistus* spp.), accounted for the mortality of many seedlings, particularly in plots of treatment A during the first two years after regeneration, and was recorded mainly during the dry season.

The fact that overall mortality, excluding the effect of *M. josephi*, was low in many plots (for example, plots of treatments B and C) suggests that mortality due to competition and drought was not high enough to regulate seedling density during the first years after seeding. Seedlings in the plots of treatment A were not colonized by *M. josephi*, probably because they were surrounded by dense vegetation. Their survival rate four years after seeding did not differ significantly from that in the plots on Mt. Carmel or at Horeshim (C and D), where some of the seedlings were artificially infested with *M. josephi* in the second year and competition with other plant species was prevented.

The very low natural infestation by *M. josephi* in the first two years after regeneration at both study sites, Mt. Carmel and Horeshim, is probably the outcome of low scale density on the neighboring trees, of the distance of the latter from the plots, and of the fact that scale development on juvenile growth of Aleppo pine is poor (Z. Mendel, unpublished data). The fact that practically none of the seedlings was injured by the scale insect in the early summer of 1991 further suggests that significant establishment of the scale during the first growing season after regeneration is not to be expected.

The potential role of *M. josephi* during the second growing season after regeneration could be evaluated in the present study only with the help of artificial infestation, since the probability that each study plot may become naturally colonized by the scale was very low. Thus, seedling mortality due to the scale differed significantly between artificially infested and uninfested plots. We may consider the ten ovisacs attached to seedlings in treatments C and D as the ten female crawlers that developed successfully in each plot. Hence, this number was high enough to produce sufficient numbers of *M. josephi* to cause the death of about 13% of the seedlings on Mt. Carmel (treatment C in 1991) (Fig. 1). The significantly lower seedling mortality rate during the same period in the corresponding plots at Horeshim was due to ants which occurred in high numbers in spring 1991 and destroyed much of the scale population.

Differences between percentages of seedlings killed by *M. josephi* in treatments B vs. C are merely due to the time of infestation. Higher mortality due to *M. josephi* is expected in plots of treatment C during the coming growing seasons. The relatively small rate of natural infestation of the seedlings suggests that major mortality due to the scale may be expected 3–5 summers after regeneration. In fact, latest results accumulated in the summer of 1994 show that the mortality rate of seedlings due to *M. josephi* was higher than 80% in the area surrounding the sampling plots on Mt. Carmel (Z. Mendel, unpublished data).

The fast death of *M. josephi*-infested seedlings resulted from the tendency of the crawlers to aggregate around the root collar of the seedling (Saphir, 1992). Therefore, mortality is expected to decrease significantly starting from the sixth year, when the tree is better protected against the scale because of the thick cork layer covering the base of the stem.

The development of *M. josephi* in Israel coincides with the growth intensity of the pine (Liphshitz and Mendel, 1989; Mendel et al., 1994a). During the dry season, plant growth is slow, the development of *M. josephi* larvae is poor and adult females whose body weight is less than half of those developing during the wet season are produced (Z. Mendel, F. Assael and N. Saphir, unpublished). This may well explain the fact that major seedling mortality due to the scale occurred during winter, spring and early summer.

Our findings also suggest that resistance to the scale of the pine regeneration on Mt. Carmel does not differ significantly from that at Horeshim, despite differences in the level of injury to adult trees at each site. Hence, our results support the hypothesis that *M. josephi* is an introduction into Israel, since so far local pine has failed to display resistance (Mendel, 1984; Mendel et al., 1994a). The mature stands on Mt. Carmel display the typical symptoms of *Matsucoccus* injury only seldom. It is suggested that Aleppo pine at an advanced age (more than 50 years) is more protected from the scale because of the thick rhytidome covering most of the stem and branches. The existence of younger stands and regeneration of nearby adult trees on Mt. Carmel appear to be the result of selection and survival of the more resistant genotypes or of the stand structure. However, there is evidence that the local population of Aleppo pine is less susceptible than populations from the western Mediterranean (Mendel, 1984). The fact that under controlled conditions (greenhouse) seedlings from Mt. Carmel tolerate higher densities of the scale than seedlings of other provenances (Z. Mendel, F. Assael, N. Saphir and A. Zehavi, unpublished data) suggests that some resistance has already developed, probably due to selection during the first years after seeding. Judging from the high rate of seedlings killed by *M. josephi*, especially in patches with dense regeneration, we expect that after several generations natural resistance will develop. Early growth in man-made forests, whose seeds could be from local relict stands, did not undergo a similar process, with spacing at the time of planting, pruning and sanitation preventing the death of susceptible genotypes and delaying injury until some 30 years after planting.

The present observations suggest that four years after fire, seedling survival in undisturbed plots, even at sites with small regeneration amidst a dense ground cover, is sufficient to produce a density adequate to establish the typical structure of a mature stand. Artificial infestation accelerated seedling mortality to a such an extent that in some of the plots all seedlings were killed by the scale insect. Considering the continuous occurrence of the scale in the plots, we may expect that surviving seedlings will be too few to produce adequate stand density. However, control (e.g. chemical) of natural scale infestation is not recommended. Seedling density in the infested plots is high enough to assure stand development, with the possibility that second-growth survivors could be less susceptible than the previous trees. In the following years data must be collected to quantify the role of *M. josephi* in the dynamics of *P. halepensis* from a natural seeding following fire.

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#### REFERENCES

- Chararas, C.** 1962. Scolytidae des Coniferes. Lechevalier, Paris. 556 pp.
- Halperin, J. and Holzschuh, C.** 1984. Contribution to the knowledge of bark beetles (Coleoptera: Scolytidae) and associated organisms in Israel. *Israel Journal of Entomology* 18:21–37.
- Karschon, K.** 1973. Natural regeneration after fire of Aleppo pine. *La-Yaaran* 23:36–38.
- Liacos, G.L.** 1977. Fire and fuel management in the pine forest and evergreen bushland ecosystems in Greece. Proceedings of the Symposium on Environmental Consequences of Fire and Fuel Management in Mediterranean Ecosystems. Palo Alto, California. pp. 289–298.
- Lipshchitz, N. and Mendel, Z.** 1989. Pathological changes in the cortex of *Pinus halepensis* are related to injury by *Matsucoccus josephi*. *Canadian Journal of Botany* 67:2692–2703.
- Mendel, Z.** 1984. Provenance as a factor in susceptibility of *Pinus halepensis* to *Matsucoccus josephi* (Homoptera: Margarodidae). *Forest Ecology and Management* 9:259–266.
- Mendel, Z.** 1992. Occurrence of *Matsucoccus josephi* in Cyprus and Turkey and its relation to decline of Aleppo pine (Homoptera: Matsucoccidae). *Entomologia Generalis* 17:299–306.
- Mendel, Z. and Lipshchitz, N.** 1988. Unseasonal latewood and encrusted pits are the cause of drying in *Pinus halepensis* and *Pinus eldarica* infested with *Matsucoccus josephi*. *Journal of Experimental Botany* 39:951–959.
- Mendel, Z., Madar, Z. and Golan, Y.** 1985. Comparison of the seasonal occurrence and behavior of seven pine bark beetles (Coleoptera: Scolytidae) in Israel. *Phytoparasitica* 13:21–32.
- Mendel, Z., Assael, F., Saphir, S., Zehavi, A. and Kafisheh, W.** 1994a. New distribution records of *Matsucoccus josephi* and *Pineus pini* (Homoptera) on pine trees in parts of the Near East. *Phytoparasitica* 22:9–18.
- Mendel, Z., Nestel, D. and Gafny, R.** 1994b. Examination of the origin of the Israeli population of *Matsucoccus josephi* (Homoptera: Matsucoccidae) using random amplified polymorphic DNA-polymerase chain reaction method. *Annals of the Entomological Society of America* 87:165–169.
- Mendel, Z., Saphir, N. and Robinson, D.** 1990a. Mass rearing of the Israeli pine bast scale *Matsucoccus josephi* (Homoptera: Margarodidae), with notes on its biology and mating behavior. *Annals of the Entomological Society of America* 83:532–537.
- Mendel, Z., Zehavi, A., Tam, S. and Madar, Z.** 1990b. The Israeli pine bast scale, *Matsucoccus josephi* and its relation to forest fires. *Hassadeh* 70:607–608 (in Hebrew, with English abstract).
- Mirov, N.T.** 1967. The Genus *Pinus*. Ronald Press, New York. 602 pp.
- Ne'eman, G., Lahav, H. and Izhaki, I.** 1992. Spatial pattern of seedlings 1 year after fire in a Mediterranean pine forest. *Oecologia* 91:365–370.
- Saphir, N.** 1992. Within-tree distribution of the Israeli pine bast scale (*Matsucoccus josephi*) in Aleppo pine (*Pinus halepensis*). M.Sc. Thesis, The Hebrew University of Jerusalem, Rehovot, Israel. 72 pp. (in Hebrew, with English abstract).
- Schiller, G.** 1979. Factors involved in natural regeneration of Aleppo pine. Pamphlet of the Division of Scientific Publications, The Volcani Center, Bet-Dagan, Israel, No. 201. 90 pp. (in Hebrew, with English summary).
- Trabaud, L., Michels, C. and Grossman, J.** 1985. Recovery of burned *Pinus halepensis* Mill. forests. II. Pine reconstitution after wild-fire. *Forest Ecology and Management* 13:167–179.

**BIO-ETHOLOGICAL OBSERVATIONS ON *PHENACOCCLUS MADEIRENSIS*  
GREEN (COCCOIDEA: PSEUDOCOCCIDAE) IN SICILY<sup>1</sup>**

ANGELA SINACORI

*Istituto di Entomologia Agraria, Università degli Studi di Palermo,  
Viale delle Scienze 13, 90128 Palermo, Italy*

**ABSTRACT**

*Phenacoccus madeirensis* Green was found for the first time in western Sicily in 1991. From the observations up to now, it results that although the species develops preferably on both *Erythrina viarum* Tod. and *Acanthus mollis* L., it has been found living on other 40 host plants. *P. madeirensis* accomplishes 5-6 generations per year and overwinters as both 1st- and 2nd-instar larvae; nevertheless, some female adults may also be found. The duration of the different developmental stages at 30 + 2°C is as follows: egg, 1-4 days; 1st instar, 3-4 days; 2nd instar, 7-8 days; 3rd instar, 6-7 days; adult female, 5-8 days.

KEY WORDS: *Phenacoccus madeirensis*, mealybug, bio-ethology, Sicily.

**INTRODUCTION**

*Phenacoccus madeirensis* Green has been found abundantly on Coral tree (*Erythrina viarum* Tod.) and *Acanthus mollis* L. in the garden of the Istituto di Entomologia Agraria, Palermo, in summer 1991. This mealybug is common in Africa and South America. In Italy it was found for the first time by Tranfaglia (1981) in Campania and by Marotta (1987, 1990) in Basilicata. Longo and Russo (1990) found *P. madeirensis* in eastern Sicily and Sinacori (1993) found it in western Sicily.

As the mealybug is harmful not only for ornamental plants (Longo et al., 1994; Sinacori and Tsolakis, 1994) but also for crops such as *Citrus* spp., *Manihot* sp., *Ananas comosus*, *Solatum tuberosum*, *Helianthus* sp., etc. (Williams, 1987; Williams and Granara de Willink, 1992) and as only limited information is available on its biology, it was decided to carry out the present research. Observations were done from June 1992 to February 1994.

**MATERIALS AND METHODS**

The phenology of the mealybug in the field was checked by collecting 20 leaves of *A. mollis* and 50 leaves of *Lantana camara* at random every 15 days; only during August samples were taken every 10 days. A surface of 3 x 3 cm per each leaf of *Acanthus* and of 2 x 2 cm per each leaf of *Lantana* was examined under a stereomicroscope, recording the different stages of the mealybug and the possible presence of natural enemies.

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Laboratory observations were carried out on potato sprouts artificially infested by first-instar larvae at a temperature of  $30 \pm 2^\circ\text{C}$  and at  $70 \pm 5\%$  RH. Observations were performed daily until the juveniles reached adulthood.

During May–October 1994 the fecundity of the females was checked on 72 individuals collecting 3–4 females with their ovisacs in the field every 10 days. The time necessary to complete the ovisac as well as the egg incubation period was ascertained on 42 individuals.

Every female collected in the field was kept in a plastic Petri dish (5 cm diameter, 1.5 cm height). Two holes were made on the lid and covered with tulle; wet cotton wool was put inside the Petri dishes to supply water. New females collected in the field were introduced every 10 days. Observations were performed daily.

### RESULTS AND DISCUSSION

From the field observations we see that *P. madeirensis* overwintered mostly as 1st and 2nd instar and seldom in the other stages (Figs. 1 and 2). The overwintering stages were found under the main veins of *Acanthus* leaves, in the crevices of the bark of *Erythrina*, or under leaves of *Pelargonium* sp.

Adult females of the first generation appeared in the third decade of June 1992 and between the third decade of May and the first decade of June 1993 (Figs. 1 and 2).

First- and second-instar larvae originating from the above mentioned females remained around the body of the mother in small colonies; then they started to move singly or in groups of 3–4 individuals towards the most protected parts of the host plant, where they remained until they attained adulthood (first half of July in 1992, end of July in 1993). As soon as the infestation increased, the various stages of the mealybug invaded the plants entirely, forming dense colonies. The time females required to complete their ovisacs ranged from 1 day (July, August) to 4 days (June, September) with an average of 1.7 days. The incubation period ranged from 1 day (August) to 6 days (October), with an average of 2.6 days. Although the number of females taken into account was not high, from the results obtained we may state that both the time necessary to complete the ovisac and the incubation period were influenced by



Fig. 1. Phenology of different stages of *Phenacoccus madeirensis* Green in the field during 1992.

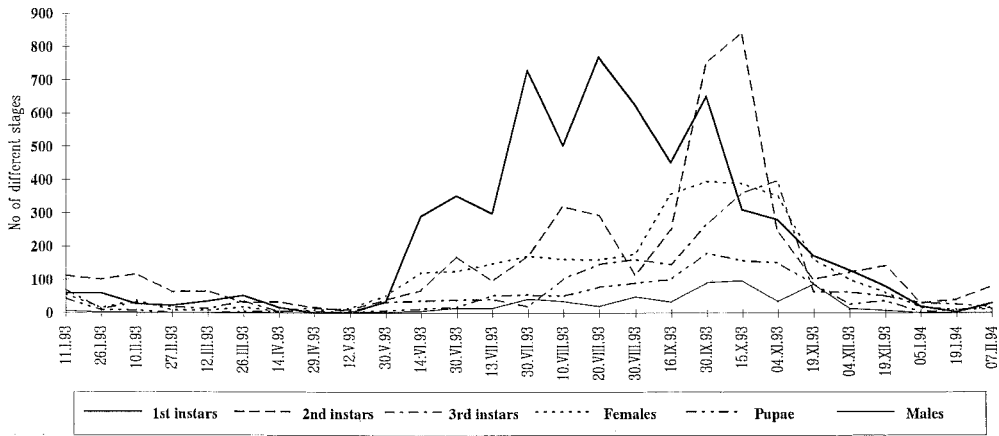


Fig. 2. Phenology of different stages of *Phenacoccus madeirensis* Green in the field during 1993–1994.

temperature. The average length of oviposition was 4.4 days, with a range of 2–7 days. We also noted some hatchings the day after oviposition, often even before females completed their ovisacs.

As far as oviposition is concerned, we see from Fig. 3 that it increased from May onward, reaching a peak during the third decade of August, and started decreasing soon afterwards. From the same figure we can also notice that the mean number of eggs laid in May was almost one third of the mean number of eggs laid during the second decade of October. Such data show that the reduced fecundity of the females was most probably linked to nutrition; as a matter of fact, females found in May derived from overwintering instars. The minimum and maximum number of eggs per female was 95 and 664.

The duration of the different stages was as follows: 1st instar, 3–4 days; 2nd instar, 7–8 days; 3rd instar, 6–7 days; female, 5–8 days (Table 1). The life cycle ranged from 22 to 31 days.

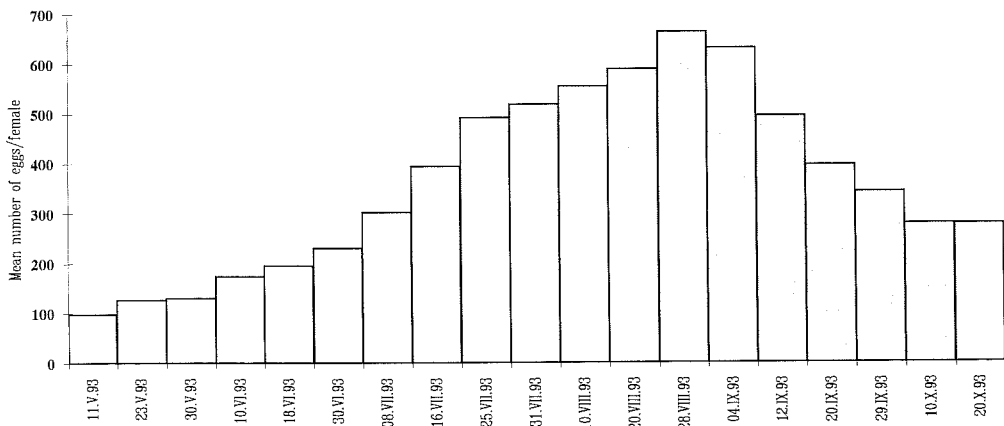


Fig. 3. Oviposition trend of *Phenacoccus madeirensis* Green.

TABLE 1  
Postembryonic development of *Phenacoccus madeirensis* Green:  
duration of the different stages

Stages	Average duration (days)	Range (days)
Egg	2.6	1–4
1st instar	3.3	3–4
2nd instar	7.2	7–8
3rd instar	6.3	6–7
Adult (female)	7.0	5–8
Total	26.4	22–31

From our observations we may say that *P. madeirensis* in western Sicily accomplished 5–6 generations per year, as was also observed by Marotta (1990) in Basilicata. However, unlike him, we found very few females laying eggs in winter.

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#### REFERENCES

- Longo, S., Mazzeo, G. and Russo, A.** 1994. Le cocciniglie delle piante ornamentali in Italia meridionale. *Informatore fitopatologico* 5:15–28.
- Longo, S. and Russo, A.** 1990. New Records on Scale Insects of Calabria and Sicily (Italy) (Homoptera: Coccoidea). Proceedings of the Sixth International Symposium of Scale Insect Studies, Kraków II:113–116.
- Marotta, S.** 1987. An annotated list of Italian mealybugs (Pseudococcidae). *Bollettino del Laboratorio di Entomologia Agraria 'Filippo Silvestri'* (Supplement, 1986) 43:107–116.
- Marotta, S.** 1990. Studio morfosistemico delle specie italiane della famiglia Pseudococcidae (Homoptera, Coccoidea). Tesi di dottorato. Università di Napoli, Napoli. 300 pp.
- Sinacori, A.** 1993. A insidiare le piante ornamentali c'è anche un'altra cocciniglia. *Sicilia agricola* 9:21.
- Sinacori, A. and Tsolakis H.** 1994. *Phenacoccus madeirensis* Green (Coccoidea, Pseudococcidae): cocciniglia di recente introduzione in Sicilia. *Informatore fitopatologico* 10:37–40.
- Tranfaglia, A.** 1981. Studi sugli Homoptera Coccoidea. V. Notizie morfosistematiche su alcune specie di cocciniglie con descrizione di tre nuove specie di Pseudococcidi. *Bollettino del Laboratorio di Entomologia Agraria 'Filippo Silvestri'* 38:3–28.
- Williams, D.J.** 1987. *Phenacoccus gossypii* Townsend and Cockerell, *P. madeirensis* Green and some related mealybug species (Homoptera: Pseudococcidae). *Bulletin of Entomological Research* 77:335–356.
- Williams, D.J. and Granara de Willink, M.C.** 1992. Mealybugs of Central and South America. CAB International, Wallington, Oxon, UK. 634 pp.