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Susceptibility of Avocado Cultivars to the Pyriform Scale, *Protopulvinaria pyriformis* (Cockerell) (Homoptera: Coccidae)

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ABSTRACT

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Since 1980 the pyriform scale, *Protopulvinaria pyriformis* (Cockerell) (Homoptera: Coccidae), has been an important pest of avocado in Israel.

Field evaluation showed differences in the susceptibility of avocado cultivars to *P. pyriformis*; Nabal were the most infested, followed by Hass and Fuerte, whereas Ettinger was sometimes attacked when located close to infested Nabal or Hass trees.

In a laboratory experiment *P. pyriformis* was able to develop and to reproduce on Nabal, Ein Vered and, to a lesser extent, on Hass. Survival of *P. pyriformis* populations was very low on Fuerte, Horshim and Wurz cultivars, whereas *P. pyriformis* settled more successfully on Ettinger, Pinkerton and Reed. Results from the laboratory experiment confirmed the actual infestation rates in avocado orchards.

INTRODUCTION

The pyriform scale, *Protopulvinaria pyriformis* (Cockerell), is a widely-distributed, economically-important pest of many agricultural crops including avocado, citrus, guava and several ornamentals. The pest is recorded from several countries of South, North and Central America, West Indies, Africa, Asia and the Mediterranean basin (Wysoki, 1987), on at least 135 plant species of 50 families (Riddick, 1955; Ben-Dov, 1985; Wysoki, 1985).

The Israeli Quarantine Service intercepted *P. pyriformis* in 1974 on the Umbrella tree, *Schefflera* sp. (Araliaceae) and it was discovered on a single avo-

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cado tree in 1980 (Ben-Dov and Amitai, 1980). In the following years, *P. pyriformis* spread along the Coastal Plain, to which it is so far restricted in its distribution, and has become an important pest of avocado and ornamentals (Ben-Dov and Amitai, 1980; Izhar et al., 1985; Swirski et al., 1987). It was recorded on 19 plant species by Ben-Dov (1985) and was discovered on more plants recently.

At high infestation levels, serious damage resulting in early leaf drop and yield reduction is caused by the feeding of the insect, and by the growth of sooty mould on honeydew, which interferes with photosynthesis and respiration. In avocado plantations emphasis is now being placed on the introduction of natural enemies (Swirski et al., 1986), with the introduction of two parasitic wasps, *Metaphycus stanleyi* Compere and *M. swirskii* Annecke & Mynhardt (Hymenoptera: Encyrtidae), from South Africa and Kenya.

The aim of the present study was to compare the susceptibility of avocado cultivars to *P. pyriformis*. Laboratory experiments were carried out to determine settling preferences, survival rate, generation time and fecundity of *P. pyriformis* on 7 commercially important avocado cultivars (Ettinger, Fuerte, Hass, Nabal, Pinkerton, Reed and Wurz) and 2 local ones (Ein Vered and Horshim). In orchards an evaluation was carried out to determine the susceptibility of 7 cultivars. In addition the phototactic and geotactic responses of crawlers were tested.

MATERIALS AND METHODS

Light and geotactic responses

Experiments on geotactic and phototactic responses, as well as on settling preferences, were carried out with 1- or 2-day-old crawlers. Eggs were obtained from ovipositing females, collected from leaves of different avocado cultivars and incubated at $25 \pm 0.2\,^{\circ}C$ and $70 \pm 5\%$ RH.

Light response was tested using the method of Washburn and Frankie (1985), i.e. several hundred crawlers were brushed onto the centre of a 30-cm horizontal glass bar, divided into 10 segments of equal length. A light source (cool white, 4500 K) was focused above 1 randomly chosen segment, and the crawlers were allowed to move about for approximately 30 min. At the end of this period the number of crawlers in each segment was counted. Geotactic response was tested by brushing several crawlers in the middle, on the outside, of a 12-cm glass tubing (diameter 2.5 cm). The tube, divided into 4 segments, was placed perpendicularly in a dark box and crawlers were allowed to move about for 30 min. Afterwards crawlers were counted in each segment. Six replicates were conducted for each test and additional tests were carried out to check phototactic and geotactic responses after 1 h exposure to light and gravity, respectively, at the above-mentioned conditions.

Settling preferences

To determine settling preferences, crawlers were placed on plants of 9 grafted avocado cultivars in June 1986 (Table 1). For each cultivar, 150 newly-emerged crawlers were put on each of 3–4 potted seedlings. Introduction occurred by placing a container (plastic vial, 1 cm high and 2.5 cm in diameter), with a funnel-shaped extension of folded black filter paper, against the stem of the seedling, approximately 10 cm above soil level. The crawlers were allowed to walk up the plant and settle. Infested seedlings were kept in a controlled cabinet (25 ± 2 °C; 65 ± 5% RH; dark/light period 8:16, with 4 cool white (4500 K) and 2 plant growth light tubes).

Eleven days after initial infestation, the containers were checked for dead crawlers. Every 3–4 weeks all plants were examined for both dead and live scales. For each leaf, the number of scales, settling site and developmental stage of the insects were recorded. Ovipositing females were collected and measured and the numbers of eggs and empty shells were counted.

Field evaluation

A field evaluation was carried out (1985–1986) to determine the susceptibility of some commercial avocado cultivars to *P. pyriformis* in orchards and to compare laboratory and field populations of the pyriform scale. Leaves of 7 cultivars were examined to determine insect density, dimensions of ovipositing females and the number of eggs female^{-1}. Special attention was paid to 4 commercially-important cultivars, i.e. Nabal, Hass, Fuerte and Ettinger. Leaves of these cultivars were collected at 7 locations in Israel (see Table 3) and the

TABLE 1

Origin and rootstocks[1] of the avocado cultivars used in the laboratory experiments

Cultivar	Origin	Rootstock
Nabal	Guatemalan	Maoz
Reed	Guatemalan	Degania 117
Wurz	Guatemalan	Degania 117
Pinkerton	Guatemalan	Degania 117
Ein Vered	Guatemalan	Zrifin 99
Horshim	Guatemalan[2]	Unknown
Fuerte	Mexican-Guatemalan	Nahlat 3
Ettinger	Mexican-Guatemalan	Degania 117
Hass	Mexican-Guatemalan	Nahlat 3

[1]Rootstocks are all of West Indian origin.
[2]May have been interbred with Mexican cultivar.

number of scales leaf^{-1} was counted. At each location 10 leaves from each of 10 trees cultivar^{-1} were checked.

Data of all experiments were evaluated statistically using ANOVA and means compared using Duncan's Multiple Range Test.

RESULTS AND DISCUSSION

Light and geotactic responses

After 30 min, in the 6 light-response tests, approximately 40% of the crawlers were found in the illuminated segment of the glass bar. When crawlers were allowed to move for 1 h, this figure was 50%. In the geotaxis tests, crawlers of *P. pyriformis* did not show any geotactic response after half an hour. However, when the crawlers were allowed to move for 1 h, they were found mainly in the upper parts of the plants, indicating a negative geotaxis.

Phototactic responses have been investigated for several scale insects (Bodenheimer, 1951; Washburn and Frankie, 1985) but geotactic responses have seldom been studied (Beardsley and Gonzales, 1975). However, in some species, like *Aonidiella aurantii* (Maskell), *Pulvinariella mesembryanthemi* (Vallot), *Pulvinaria delottoi* Gill (Washburn and Frankie, 1985) and *Coccus hesperidum* L. (Bodenheimer, 1951), the mobile stages are known to be negative-geotactic.

The light-response tests indicate that *P. pyriformis* crawlers are positive-phototrophic but are less attracted to light than those of *P. mesembryanthemi* and *P. delottoi* (Washburn and Frankie, 1985). In the gravity tests *P. pyriformis* showed no clear geotaxis.

Settling preferences

Figure 1 shows the survivorship of *P. pyriformis* populations on the different avocado cultivars. High mortality occurred in the early stages: after 11 days mortality was high and varied from 62% on Reed to 96% on Horshim (average 81%). After settling, mortality decreased to an average of 39% month^{-1}, although there were considerable differences depending on cultivar. One hundred and thirty days after settling, mortality of *P. pyriformis* increased sharply on plants of all cultivars.

Statistical analysis of the survival data revealed that scales on cultivars Nabal and Ein Vered had significantly higher survival rates than on other cultivars, except for Reed. Settlers on Pinkerton and Ettinger had lower survival rates than on Nabal, Ein Vered and Reed, but higher survival than on Wurz, Fuerte and Horshim. The development of *P. pyriformis* was relatively fast on Nabal, Ein Vered, Hass and Pinkerton (pre-ovipositing females after 75 days), but slower on Reed and Ettinger (only pre-ovipositing females after 100 days).

Except for 1 Reed plant, where crawlers were found on the stem (all of them

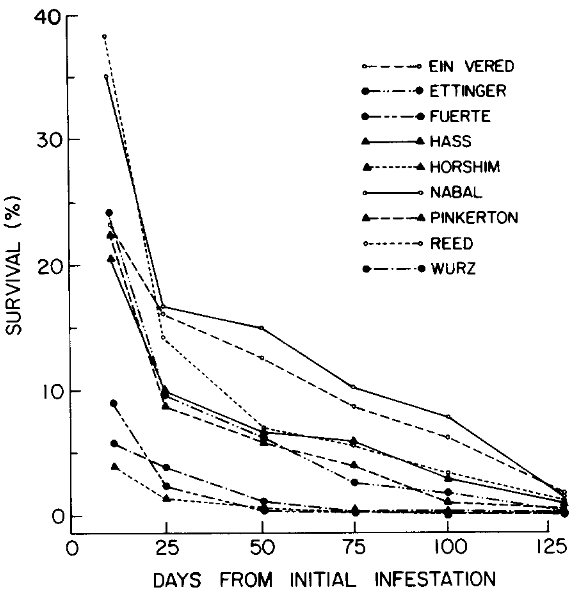

Fig. 1. Survival of laboratory populations of *Protopulvinaria pyriformis* on seedlings of 9 avocado cultivars (150 crawlers plant^{-1}).

were dead 25 days after initial infestation), settlers were found exclusively on the underside of leaves near middle-or small-sized vessels. The distribution of *P. pyriformis* on plants arbitrarily divided into lower, central and upper parts, was tested statistically. After 11 days on Ein Vered and Fuerte cultivars, settlers were more abundant in the lower than in the upper part. On other cultivars, settlers were evenly distributed among the three parts. After 2 months, except for Hass, plants of all cultivars showed even distribution of *P. pyriformis*. On Hass, most settlers were found on the young leaves at the top of the plant.

First-instar crawlers of scales are very vulnerable to unfavourable climatic conditions; temperature and relative humidity can affect settling success to a great extent (Beardsley and Gonzalez, 1975; Washburn and Frankie, 1985). After 11 days, average mortality of the first instar was 81%, but was lower on Reed, Nabal and Ein Vered (Fig. 1). More scales were found on Nabal and Ein Vered than on other cultivars. Once the scales had settled, differences between *P. pyriformis* populations on the avocado cultivars seemed to consist of differences in growth rates; females laying eggs on Nabal and Ein Vered, whereas on Fuerte, Wurz and Horshim second and third instars only were found. A comparison of Nabal, Ein Vered and Hass revealed that conditions were non-optimal for *P. pyriformis* on Hass, whereas on Nabal and Ein Vered *P. pyriformis* developed well. The fecundity data of scales on the 2 latter cultivars suggested a lower fecundity with accelerated development.

Ovipositing females on Nabal and Ein Vered were similar in size (2.44 × 2.31

mm) and fecundity (170 vs. 202 eggs on average). However, it should be noted that on Nabal and Ein Vered 10 early-laying females produced fewer eggs (124 and 144, respectively) than females laying 3 weeks later (232 and 284, respectively). Two females only matured on Hass, which were not included in the statistics.

Development seemed delayed on some cultivars as first instars could still be found 75 days after initial infestation. For scales on Nabal, Ein Vered and Hass, the generation time varied between 80 and 135 days. Differences in numbers of *P. pyriformis* on seedlings of the 9 avocado varieties tested were caused principally by differences in the initial success of colonization and settlement of crawlers.

Field evaluation

Field ovipositing females were significantly longer and wider on Fuerte and Benik than those on Ettinger and Reed, while females on Hass, Nabal and Anaheim were intermediate. On average females on Nabal and Hass laid more eggs than on Ettinger, Anaheim and Reed, but as many as on Benik and Fuerte. Differences in overall density between cultivars were clear: on leaves of Nabal and Hass density was 4 times higher than on leaves of Fuerte and 20 times higher than on leaves of Ettinger and Anaheim (Table 2). Total number of scales (Table 3) differed clearly, Nabal being more severely attacked than Hass. Fuerte and Ettinger had low infestation rates. Finally, the infestation level was similar in the 7 locations in Israel.

It is remarkable that *P. pyriformis* females on field Fuerte were quite large and highly fecund — although less so than on Nabal and Hass in the field— because Fuerte was not particular sensitive to *P. pyriformis* in the laboratory.

TABLE 2

Dimensions, fecundity and density of *Protopulvinaria pyriformis*, collected from avocado orchards at Miqwe Yisra'el (MI) and Nahshonim (N)[1] (based on 20 specimens of each cultivar)

Cultivar	Site	Length (mm)	Width (mm)	Number of eggs	Density (cm^{-2})
Fuerte	MI	2.88[a]	2.69[a]	207[a]	3.4[b]
Benik	N	2.81[ab]	2.64[a]	225[a]	0.8[c]
Hass	MI	2.77[ab]	2.54[ab]	234[a]	13.4[a]
Nabal	MI	2.72[bc]	2.58[a]	239[a]	14.7[a]
Anaheim	N	2.68[bc]	2.57[a]	148[b]	0.5[c]
Ettinger	N	2.60[c]	2.42[b]	156[b]	0.7[c]
Reed	N	1.68[d]	1.56[c]	100[b]	-

[1]Within columns, means followed by a common superscript do not differ significantly (ANOVA and Duncan's Multiple Range Test, $P<0.05$).

TABLE 3

Number of *Protopulvinaria pyriformis* avocado leaf^{-1}. Four cultivars from 7 locations in Israel

Cultivar	Site							Mean[1]
	Bet Dagan	Einat	Gan Yehuda	haHorshim	Kefar haYarok	Miqwe Yisra'el	Nahshonim	
Ettinger	1.9	0	-	0	-	1.2	0	0.6^c
Fuerte	0.8	0	-	0.1	0	0.6	-	0.3^c
Hass	10.9	0.5	129.8	23.4	4.4	2.7	2.7	24.9^b
Nabal	215.1	126.1	-	825.8	290.1	118.9	126.4	284.6^a

[1]Means with a common superscript do not differ significantly (ANOVA and Duncan's Multiple Range Test, $P<0.05$).

P. pyriformis did not reach high population levels on Ettinger and Reed in either the field or the laboratory, yet in Israel (Na'an) and in Spain, Reed may, like Hass, be heavily attacked by *P. pyriformis*.

A correlation between high susceptibility to *P. pyriformis* and the origin of the cultivar or rootstock could not be detected. As regards the origin of the variety, Nabal and Ein Vered are both of Guatemalan origin, like Reed, Pinkerton and Wurz, which are less suitable hosts. Hass is of Mexican–Guatemalan origin, like Fuerte and Ettinger; the latter 2, however, did not provide good survival conditions for *P. pyriformis* in the laboratory. Correlations with rootstock or origin of rootstock can not be made.

Preferences to avocado cultivars can also be found in 2 other pests. Hass, Nabal and, to a lesser extent, Benik, Anaheim, Fuerte and Ettinger, in decreasing order of susceptibility, have been attacked by the long-tailed mealybug, *Pseudococcus longispinus* Targioni-Tozzetti (Wysoki et al., 1977). The greenhouse thrips, *Heliothrips haemorrhoidalis* (Bouche), prefers Northrop, Puebla, Mexicola, Hass, Benik, Itzamna, Carlsbad, Queen, Panchoy and Milly-C (Avidov and Ben-Haim, 1950a,b; Ebeling, 1959; Anonymous, 1987; Swirski et al., 1987); less susceptible cultivars are Anaheim, Nabal, Fuerte and Dickinson (Ebeling, 1959). However, in Israel *H. haemorrhoidalis* caused serious problems on Stuart and Maoz (Swirski et al., 1981) which were abandoned and Fuerte, Nabal and Ettinger are now attacked (Swirski et al., 1981, 1987, 1988).

Because the Nabal cultivar shows high susceptibility to *P. pyriformis*, this cultivar has been uprooted in low-profit orchards and in others more resistant and high-yielding cultivars have been grafted on Nabal. This susceptible cultivar is not recommended for new orchards.

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