

POPULATION DYNAMICS OF THE MANGO SCALE, *AULACASPIS TUBERCULARIS* (NEWSTEAD) (COCCOIDEA: DIASPIDIDAE), IN SOUTH AFRICA

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ABSTRACT

Ecological aspects such as population composition, population fluctuation and spatial distribution as well as the natural enemies of *Aulacaspis tubercularis* (Newstead) (Coccoidea: Diaspididae) were analyzed using data gathered from two localities, viz. Kaapmuiden (25°29'S, 31°24'E) and Nelspruit (25°27'S, 30°58'E), South Africa. An average of 350 females and 550 males were examined fortnightly for a period of 12 months to determine the frequency of the developmental stages and the percentage parasitism. Eight leaves per tree, two in each quadrant, were randomly picked to determine the relative abundance and the spatial distribution of the scale insects within the tree. Twenty randomly selected trees in an orchard were used for this purpose. The highest infestation of the mango scale occurred on the shady south-facing lower aspect of the tree. Population peaks of the mango scale occurred at different periods of the year in the two regions monitored. The population peak at Kaapmuiden, with a higher mean temperature, occurred in August, much earlier than at Nelspruit, where it occurred in November. Generations overlapped to such an extent that no developmental stage peaks could be detected. The indigenous parasite *Encarsia citrina* (Craw) was incapable of controlling *Aulacaspis tubercularis* despite the percentage of parasitism exceeding 80% at certain times of the year. The predatory thrips, *Aleurodothrips fasciapennis* (Franklin), was probably recorded for the first time in Africa while preying on mango scale.

KEYWORDS: Diaspididae, *Aulacaspis tubercularis*, mango scale, population dynamics, South Africa.

INTRODUCTION

The mango scale, *Aulacaspis tubercularis* (Newstead) (Coccoidea: Diaspididae), is presently a widespread pest throughout all mango-producing areas in South Africa (De Villiers, 1984). Although the mango scale does not cause internal fruit damage, its cosmetic effect on the fruit skin results in a significant decrease in the ratio of exportable fruit and substantial financial losses for the mango grower. The scale insects can be nibbed off the fruit quite easily, but the marks which are left are unsightly and unacceptable to the foreign market. It is thus of utmost importance to control the scale insects before they settle on the fruit, since even if they are killed on the fruit, lesions remain. Since the scale causes blemishes on the fruit without affecting the

fruit flesh, it has become a significant pest in South Africa only during the past few years, as the demand for high quality, export fruit increased. This, and the ongoing pressure to reduce the use of chemicals in mango production, has initiated the present investigation into a possible biological or at least integrated control programme for the mango scale. According to Cock (1986), knowledge of the number of generations per year, the distribution pattern, the population fluctuations and the peaks of stages susceptible to parasitism and chemical control is a prerequisite for the implementation of an integrated pest control programme. The fact that nymphal instars of scale insects are more susceptible to certain insecticides, especially to insect growth regulators (Yarom et al., 1988; Van Duyn and Murphey, 1971; Darvas and Varjas, 1990), supports Cock's argument. The identification of peaks in the frequency of these growth stages of the mango scale could make it possible to reduce the use of chemicals by focusing the control programme on these stages. It was therefore the objective of this study to develop a better understanding of the phenology and ecology of *A. tubercularis* with the ultimate aim to establish a viable, integrated control programme of mango pests and, in particular, of the mango scale.

MATERIALS AND METHODS

Field studies were undertaken in one or more of three orchards, two of which were in the Kaapmuiden area (25°29'S, 31°24'E) and the third at Nelspruit (25°27'S, 30°58'E). These two geographical locations were chosen because of significant differences in climate and altitude between the regions. The orchards consisted of three different monoculture cultivars, namely Peach and Keitt at Kaapmuiden and Sensation at Nelspruit. The 50-year-old Peach orchard consists of large trees overlapping each other and forming dense shadows underneath. The Keitt and Sensation orchards were both 10 years old, with much smaller trees and consequently less dense. No chemical control of mango scale has ever been applied in any of these orchards. Standard disease control programmes for commercial orchards were followed throughout the duration of the study in all three orchards.

Spatial distribution of *Aulacaspis tubercularis* within the tree

Eight mango leaves per tree were sampled by randomly selecting and picking two in each quadrant (N, E, S, W), one at ± 180 cm (head height) and the other at ± 30 cm (knee height) from the ground. Eighteen randomly selected mango trees of the cultivar Sensation were sampled in the Nelspruit orchard. Leaves were examined under a stereomicroscope and all the living second-instar and adult female scale insects were counted. These counts were done fortnightly from August 1992 to February 1993.

Relative abundance

The sampling method described to determine the spatial distribution of the mango scale was also used to determine the relative abundance of the insect. For this purpose, counts were made fortnightly for 15 consecutive months, from October 1992 to February 1993, in the Sensation and Peach orchards at Nelspruit and Kaapmuiden, respectively.

Distribution of the developmental stages

The method of sampling described by De Villiers (1973) was adapted and used fortnightly for 15 consecutive months from October 1992 to February 1993. Three leaves per tree of the 18

randomly selected trees were collected in each of the three orchards. Only leaves that were seen to be moderately infested with mango scale were sampled. Approximately 50 leaves yielded enough scale insects in order to examine a total of at least 350 females and 550 males, which is the sample size to ensure a representative sample (De Villiers, 1973).

Scale insects were examined under a microscope by lifting or breaking the scale cover with a thin needle. Males and females were counted separately because of the major differences in morphology and distribution pattern of the two sexes (Labuschagne, 1993). The scattered distribution of the first-instar females made them difficult to detect. Consequently, they were not counted. All the female stages, except the first instars, were examined, while only a random sample of the males per leaf was examined.

Parasitism

Collection of natural enemies. In a survey of the natural enemies of the mango scale, scale-infested mango leaves were collected at the localities listed in Table 1.

TABLE 1
Localities and dates of mango scale collection

Locality	Collection dates		
Nelspruit	25°27'S	30°58'E	September 1991 to February 1993
Kaapmuiden	25°29'S	31°24'E	September 1991 to February 1993
Tzaneen	23°50'S	30°10'E	23 April 1992, 14 June 1992, 10 September 1992
Rustenburg	25°40'S	27°10'E	29 January 1993

Leaves were examined under a stereomicroscope and organisms seen preying on *A. tubercularis* were collected. All other scale insects were removed before the leaves were placed in emergence boxes. Parasitoids and predators emerging from *A. tubercularis*, as well as the predators collected on leaves, were identified.

Abundance of parasitoids. The method previously described to determine the distribution of the developmental stages was also used to determine the rate of parasitism of the mango scale. Only one parasitoid species, the endoparasitoid *Encarsia citrina*, was found to parasitise *A. tubercularis*. Parasitoid larvae and pupae were only found in second-instar males, pre-ovipositing females and second-instar females.

RESULTS AND DISCUSSION

Spatial distribution within the tree

Statistical analysis of the data gathered fortnightly for a period of 6 months was complicated by the population fluctuation from season to season and the patchy grouping of the insects on the leaves. A simplified idea of the spatial distribution is gained in Fig. 1, which shows the accumulated figures. It is evident that the scale is much more abundant on the lower, south-facing aspect of the tree than on any other aspect. The most likely reason for this distribution pattern is the temperature difference between the various aspects of the tree. The south-facing lower aspect is constantly in the shade, while the north-facing upper aspect is

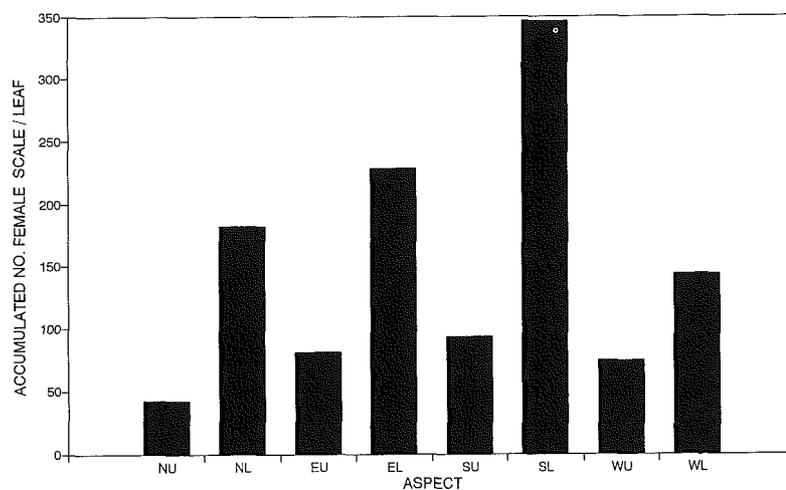


Fig. 1. The spatial distribution of mango scale, *Aulacaspis tubercularis*, in mango trees, given as accumulated counts that were done from August 1992 to February 1993 at Nelspruit (25°27'S, 30°58'E). NU = north-facing upper aspect; NL = north-facing lower aspect; EU = east-facing upper aspect; EL = east-facing lower aspect; SU = south-facing upper aspect; SL = south-facing lower aspect; WU = west-facing upper aspect; WL = west-facing lower aspect.

constantly in the sun. Bodenheimer (1951) stated that the shady centre of the tree is the preferred natural environment of the California red scale *Aonidiella aurantii* (Maskell). His results were confirmed by Carroll and Luck (1984). They came to the conclusion that low densities of *A. aurantii* were correlated to direct sunlight during hot weather.

Figure 1 also shows that mango scales were more abundant on the east-facing lower than on the west-facing lower aspect of the tree. This tendency can possibly be explained in terms of the above-mentioned publications. Although the east- and west-facing aspects of the tree get the same amount of direct sunlight, the air temperature during the morning is lower than that during the afternoon. The combined effect of the high air temperature and the direct sunlight could cause the lower infestation on the west-facing aspect. These results could have important implications. Firstly, population censuses should be sampled on the highly infested aspect of the tree, thus saving time and effort. Secondly, the chemical spray programme could be adapted to concentrate on the highly infested aspect of the tree. Trials should, however, be performed to verify these assumptions.

Relative abundance

Climatic factors, particularly temperature and humidity, affect most ecological aspects of armoured scale insects and play a major role in their population dynamics (McClure, 1990). Figures 2 and 3 show the average number of *A. tubercularis* females per leaf as well as the average fortnightly maximum and minimum temperatures at the two study sites, Nelspruit and Kaapmuiden.

The population density at Kaapmuiden was much higher than at Nelspruit for the greater part of the year (Figs. 2 and 3). The age and size of the sampled trees could probably have had an

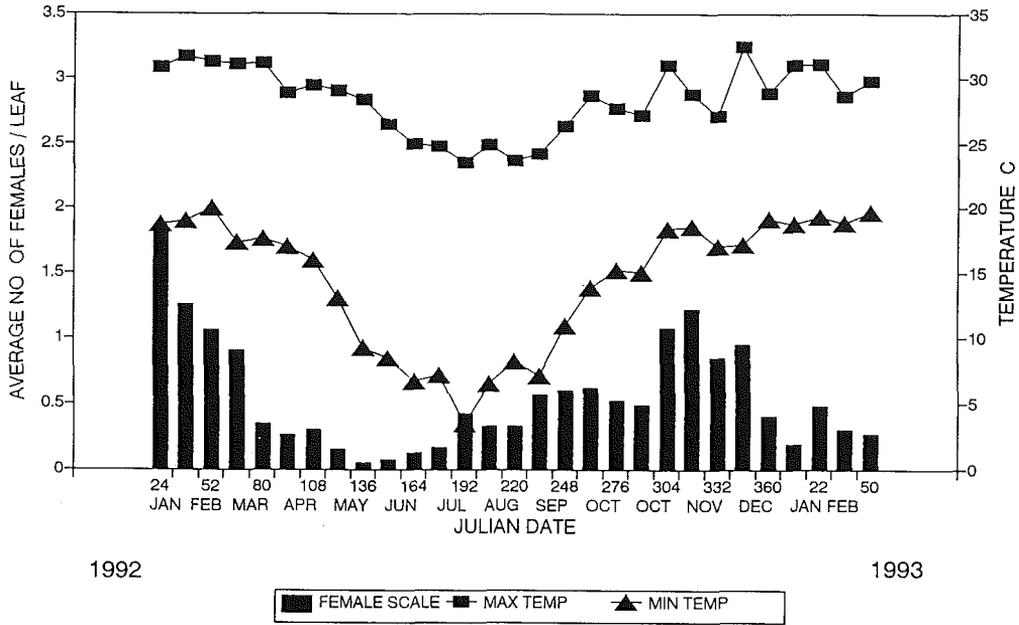


Fig. 2. Population fluctuations of *Aulacaspis tubercularis* females in a mango orchard at Nelspruit.

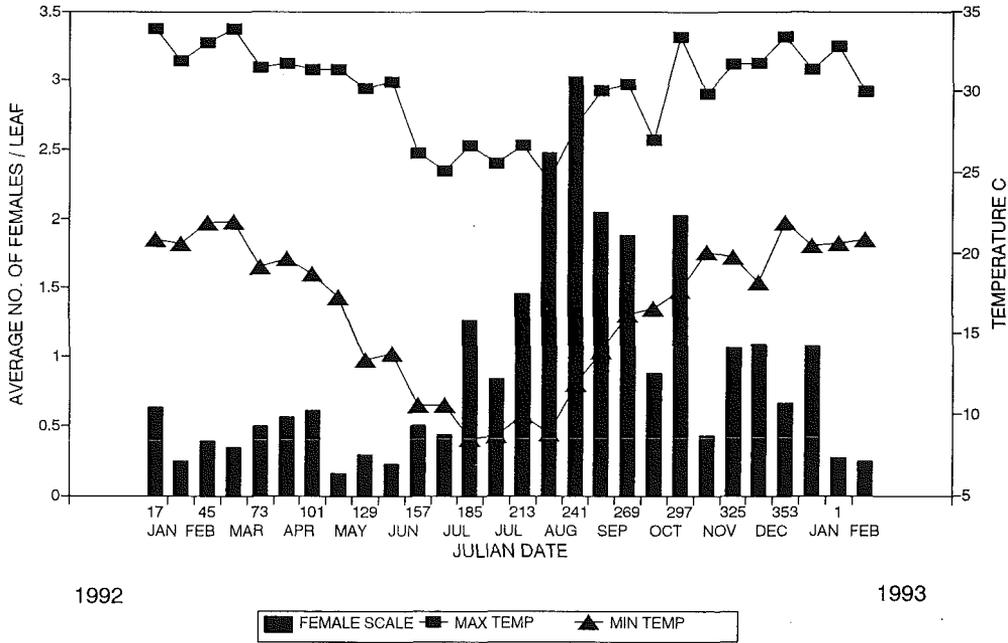


Fig. 3. Population fluctuations of *Aulacaspis tubercularis* females in a mango orchard at Kaapmuiden.

influence on the difference in population size. Nelspruit, with a lower average temperature, had population peaks in late January and at the beginning of November (Fig. 2) (average maximum–minimum temperatures for the two areas: Nelspruit, 28.4–14.4°C; Kaapmuiden, 30.2–16.5°C). Kaapmuiden, in turn, had one major population build-up about two months earlier, at the end of August (Fig. 3). It is possible, however, that there could have been a first peak earlier in January or December at Kaapmuiden. The most probable explanation for the decline in population during the summer months at Kaapmuiden is the low tolerance of the mango scale for high temperatures. No empirical data is available on the effect of extreme temperatures on mango scale, but it was observed that the mortality of laboratory-reared mango scale insects was extremely high when temperatures in rearing chambers exceeded 30°C, which occurred during breaches in temperature control. Bodenheimer (1951) investigated the difference between the body temperature of the red scale and the surrounding air temperature and found that the average temperature difference was 13.4°C when leaves were in the sun. The average difference between the body temperature of scale insects and the surrounding air in natural shade was less marked at 6.3°C. In both of these cases the body temperature of the scale insect exceeded that of the surrounding air. This could explain the population decline at Kaapmuiden at the beginning of October, after which, for a period of 7 months, the average maximum temperature nearly always exceeded 30°C. A population increase was only recorded when the average maximum temperature dropped below 30°C. The same tendency is demonstrated at Nelspruit (Fig. 2), where the high temperatures in January probably resulted in the steep decline in the mango scale population. This was again seen after the first continued spell of high temperatures in October and November.

Abdelrahman (1974) found that differential tolerance among development stages of *Aonidiella aurantii* to low temperature was the main factor determining its distribution and abundance in the field. This could also explain the situation in the Nelspruit population, where the lower temperatures may have postponed the population build-up. Laboratory experiments confirmed that the lowest reproductive rate occurred during the simulated winter conditions, while the highest reproductive rate occurred during simulated spring (Labuschagne, 1993).

The effect of growth flushes of the host tree on mango scale population fluctuation was not specifically examined. According to Schroeder (1993), leaf growth flushes during the 1991/1992 season in the Sensation orchard at Nelspruit occurred in September and again in February–March. There does seem to be a correlation between the September flush and the mango scale population increase at Nelspruit during August–September of that year (Fig. 2). However, this cannot be confirmed because of insufficient data.

The relatively high population peaks of *A. tubercularis* in August and November at Kaapmuiden and Nelspruit, respectively, coincide with the setting of the fruit. Since in a commercial orchard scale crawlers must be prevented from migrating from the leaves to the fruit, this period would probably be the most critical time in a control programme for the mango scale. On the other hand, the continuous availability of the scale throughout the year would be a distinct advantage in the establishment of exotic natural enemies.

Distribution of the developmental stages

Figures 4 and 5 demonstrate the temporal distribution of the different developmental stages of *A. tubercularis* for females and males, respectively, with the exception of first-instar females at Nelspruit. Since the results obtained in two orchards at Kaapmuiden were similar to the

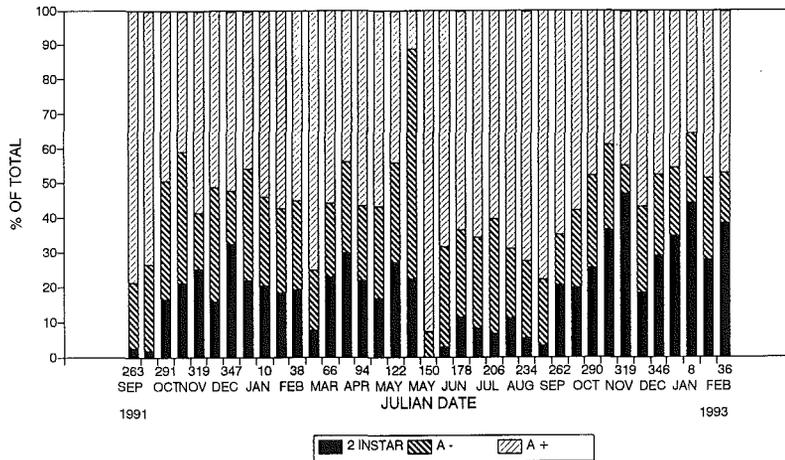


Fig. 4. Distribution of *Aulacaspis tubercularis* female instars at Nelspruit on mango cultivar Sensation for the periods September 1991 to February 1993. A- = pre-ovipositional adult stage; A+ = ovipositional adult stage.

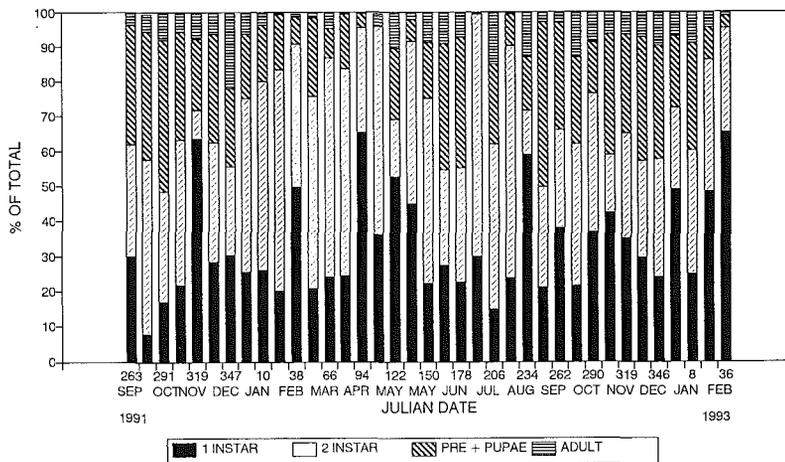


Fig. 5. Distribution of *Aulacaspis tubercularis* male instars at Nelspruit on mango cultivar Sensation from September 1991 to February 1993.

results at Nelspruit, they are not shown. No distinct generations could be identified from the results obtained in this study, probably because of the overlapping of generations.

Two principal reasons are probably responsible for this overlapping. The first is the long ovipositional period which allows the first offspring of an adult female to reach sexual maturity and start reproducing while the mother scale insect is still reproducing. The duration of the ovipositional period was found to be as long as 82 days at a day–night cycle of 26–13°C,

whereas the average duration of development (egg to egg) determined under the same conditions was 52.3 days. The average ovipositional period was of 45.69 days, which was considerably longer than the 12.6, 15.2 and 12.0 days of the first instar, second instar and pre-ovipositional adult stages, respectively (Labuschagne, 1993). This also explains the high relative abundance of the ovipositional adult stage as compared to the other developmental stages. Similarly, Williams (1970) found that the long oviposition period caused considerable overlapping of generations in *Aulacaspis tegalensis* (Zehntner).

In addition to the long ovipositional period, the pre-ovipositional period could be prolonged to approximately 42 days (Labuschagne, 1993) if fertilization did not take place, which would cause further overlapping of generations. In order to increase control efficiency it is important to be able to predict the period when the crawler population is at its peak, since the crawler stage is generally accepted to be the most susceptible to chemicals. However, it is clear that overlapping of generations makes such a prediction virtually impossible. Casual field observations seem to suggest a crawler population peak in early spring. This could be due to the increase in the total population at this time, and therefore also in the number of crawlers. The ratio of crawlers to other developmental stages needs to be determined, rather than absolute numbers, to clarify this point.

The continuous presence, throughout the year, of all the developmental stages of the scale is a major advantage for the possible implementation of a biological control programme, in that a complex of parasitoids can be accommodated and new parasitoids can be established at any time of the year.

Parasitization

Collection of natural enemies. The only mango scale parasitoid species found in the survey was *Encarsia citrina* (Craw) (Hymenoptera: Aphelinidae), previously recorded from South Africa as *Aspidiotiphagus citrinus* Craw (Viljoen, 1986).

The predatory thrips *Aleurodothrips fasciapennis* (Franklin) (Thysanoptera: Phlaeothripidae) was found preying on the mango scale. This is probably its first recording as a predator on mango scale, although this species has been reported as a predator on a number of other diaspidid scale insects outside of Africa (Lewis, 1973).

Two predatory beetles, *Rhyzobius lophanthae* (Blaisdell) (Coleoptera: Coccinellidae) and *Chilocorus nigritus* (Fabricius) (Coleoptera: Coccinellidae) have often been noticed feeding on mango scale at the study sites.

Abundance of parasitoids. The percentage parasitization, as determined by counts of parasitoid pupae and larvae from scale insects collected at Nelspruit and Kaapmuiden, is illustrated in Figs. 6 and 7. Peak periods of parasitism by *E. citrina* on mango scale are evident from the results given in these figures.

The period of parasitism for both male and female scale insects in the Nelspruit area stretched from January to June, reaching a peak in May–June. At Kaapmuiden the peak period was between April and July for female scale insects and rather erratic for males. In both localities the period of highest parasitism by *E. citrina* seemed to be from May to June. The percentage of parasitism in the Nelspruit area was as high as 80%, while that in the Kaapmuiden area was generally lower. Schoeman (1987) noted that 17.7% of the 1022 female *A. tubercularis* scale insects he examined were parasitised by *E. citrina*. He unfortunately did not mention the duration and time of his study.

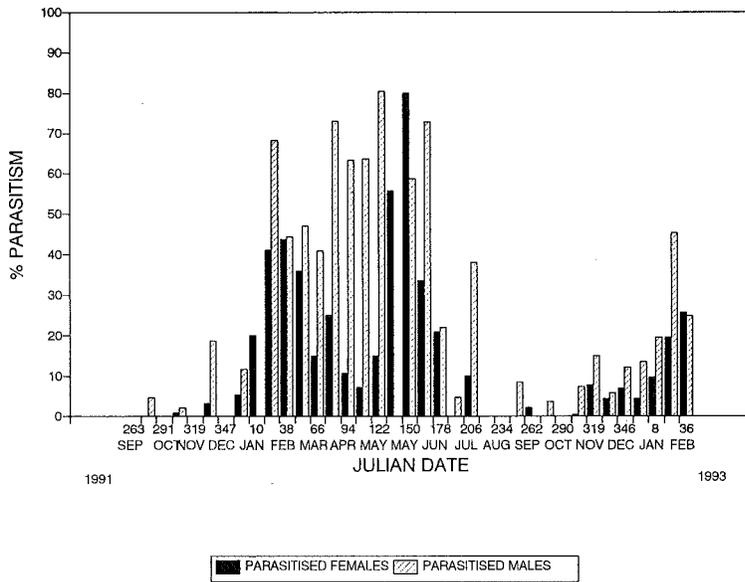


Fig. 6. Percentage of 2nd-instar and pre-ovipositional adult females (A-) and of 2nd-instar males of *Aulacaspis tubercularis* parasitised by *Encarsia citrina* on mango trees of the cultivar Sensation at Nelspruit.

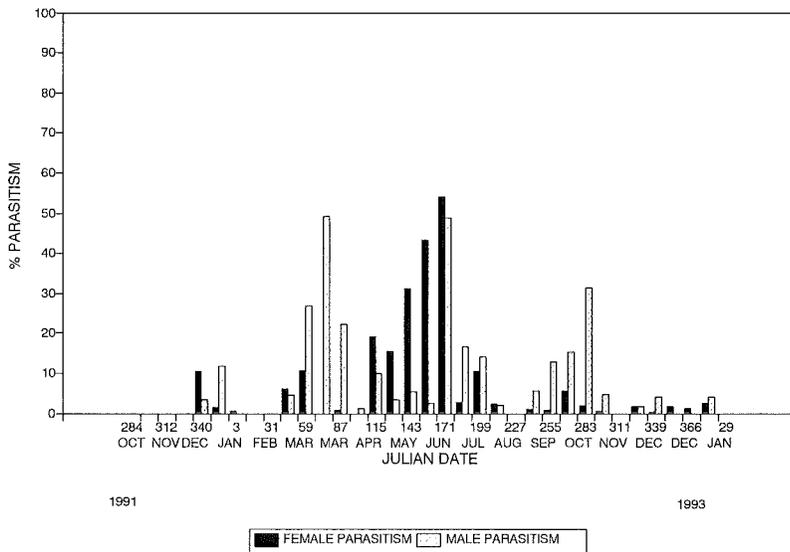


Fig. 7. Percentage of 2nd-instar and pre-ovipositional adult females (A-) and of 2nd-instar males of *Aulacaspis tubercularis* parasitised by *Encarsia citrina* on mango trees of the cultivar Peach at Kaapmuiden.

Even though the percentage parasitism in this study was relatively high, the parasitoid was not effective enough in controlling *A. tubercularis*.

If the relative abundance of *A. tubercularis* (Figs. 2 and 3) is compared with the percentage parasitism (Figs. 6 and 7), it is obvious that a peak of parasitism is followed by a population peak of the mango scale. This situation is better illustrated in Figs. 8 and 9, where the relationship between scale insect density and percent parasitism is illustrated. The scale insect density in both areas is virtually inversely proportionate to the percentage parasitism by *E. citrina*. Density dependence could not be indicated and parasitism by *E. citrina* could therefore not be a regulative mortality factor. Although the effect of parasitism on the mortality rate of the mango scale is relatively small, the combined effect of predators and the parasitoid could be significant. This postulate is a subject for further study. An estimation of the impact that other natural enemies have on the mango scale population should be made before a biological control programme can be implemented.

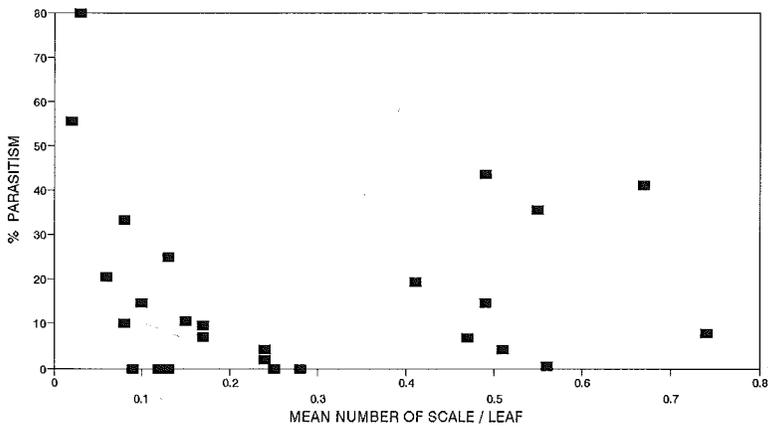


Fig. 8. Dependence of *Encarsia citrina* density at Nelspruit on its host, *Aulacaspis tubercularis*.

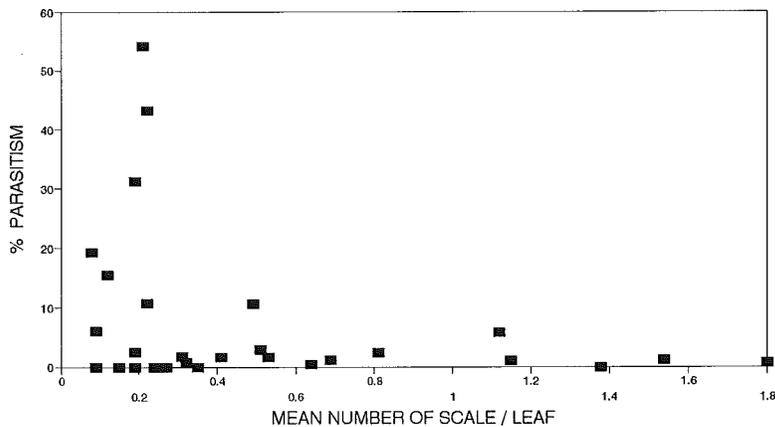


Fig. 9. Dependence of *Encarsia citrina* density at Kaapmuiden on its host, *Aulacaspis tubercularis*.

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