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Patterns of hatching and winter survival were studied on the eggs of non-diapausing populations of *Panonychus citri* (McGregor) on pear and citrus in Takatsuki, Osaka Prefecture, together with changes in population density and stage structure of the populations.

Most non-diapausing eggs laid on pear twigs in autumn hatched by mid-December and the individuals that hatched from the eggs all starved to death. Eggs that had not hatched by that time could not successfully overwinter at all, whereas on citrus the eggs as well as the other stages survived the winter. On pear no individuals of *P. citri* were observed until mid-August but thereafter the population showed a rapid increase to an outbreak level. These results showed that the non-diapausing population on pear cannot maintain itself throughout the year and the population consists of immigrants from outside of the pear orchard.

INTRODUCTION

There are two reproductively incompatible strains of the citrus red mite, *Panonychus citri* (McGregor) in Japan: one is a diapausing strain and the other is a non-diapausing strain (see, Shinkaji, 1961 a, b, 1979; Takafuji and Fujimoto, 1985; Takafuji, 1986). Shinkaji (1961 a, 1979) studied the diapause property of the eggs oviposited in autumn on twigs of deciduous fruit trees throughout Japan, and presented a line of demarcation between the distributions of the two strains.

However, on citrus the non-diapausing strain is observed in many areas located far north of the demarcation (Shinkaji, 1961 a, 1979) and recent surveys show that it also occurs in pear and peach orchards located north of the line, for example, in Okayama, western Honshu (Takafuji and Morimoto, 1983) or in Fukuchiyama in the northern part of Kyoto Prefecture (Takafuji, unpublished). But in these areas the non-diapausing strain is seen only during the period from late summer to autumn, and therefore it is very doubtful that the populations maintain themselves throughout the winter (Takafuji and Morimoto, 1983).

On the other hand, Shinkaji (1961 b) showed that in a pear orchard located south of the demarcation, non-diapausing eggs survive and hatch throughout the winter.

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until mid-April, though in this case too it is not certain whether the population starts from individuals that have overwintered on pear.

The pear orchard in Takatsuki, Osaka Prefecture studied in the present paper is located slightly north of the demarcation between the diapausing and non-diapausing strains. The population occurring here is exclusively of non-diapausing strain (FUJIMOTO and TAKAFUJI, unpublished). Each autumn it reaches outbreak levels and numerous eggs are laid on twigs of pear trees. The present paper reports the study of the hatching and mortality patterns of the eggs laid on twigs in autumn and the seasonal occurrence of the population, thereby elucidating whether or not the population is successfully overwintering on pear. For comparison, the same study was carried out on a population occurring on citrus near the pear orchard and also on a population of diapausing strain which was artificially introduced onto potted pear trees.

MATERIALS AND METHODS

Field population census and egg collection for the non-diapausing strain were carried out in the Experimental Farm of Kyoto University located in Takatsuki, Osaka Prefecture. Several varieties of pear were separately grown in groups of 20 to 30 trees in the Farm. For the present study a group of 30 Nijyusseiki pear trees were chosen. Only 100 m apart from the pear orchard, a group of 4 satsuma mandarin (Citrus unshiu MARC.) were grown.

To record patterns of hatching and mortality of the eggs of the citrus red mite, those laid in autumn of 1984 were collected, as it was very difficult to directly observe the eggs on trees. At each sampling around 20 citrus leaves with mites were taken.

![Fig. 1. Changes in mean air temperature in Takatsuki (●) and Kyoto (—) at 5-day intervals. The horizontal line is the developmental zero (8.0°C) for the eggs of the non-diapausing strain of P. citri (FUKUDA and SHINKAI, 1954).](image-url)
from the 4 citrus trees and 8 twigs from pear trees where mites occurred in high densities. Eggs which had hatched, died or had been injured, and stages other than eggs were removed, leaving only eggs alive. The leaves and twigs were then cut into small pieces and after counting the number of eggs on each piece they were placed on slightly moistened cotton in petri dishes (9 cm in diameter and 1.4 cm in depth). The petri dishes were kept outdoors on the north side of a building on the campus of Kyoto University in Kyoto City, where they were protected from rainfall. Hatching and mortality of the eggs were examined under a microscope at intervals of 2 to 4 days until all hatched or died. To confirm the winter survival of the non-diapausing eggs on pear under natural conditions in the orchard, about 500 eggs laid on twigs in the autumn of 1984 were collected from pear trees on March 10, 1985 and observed under a microscope. The mean daily temperature at Kyoto was quite similar to that at Takatsuki during the observation period (Fig. 1).

For comparison with the hatching and mortality patterns of the non-diapausing strain, those for a diapausing strain were also studied: eggs were collected from the twigs of 2 potted pear trees placed on the campus of Kyoto University in the autumn of 1984. This diapausing strain originated from a population on pear in Amagi, northern Kyushu.

To record the seasonal occurrences of the mites in the field, 80 leaves were sampled at random from the 4 citrus trees (20 from each) and 50 leaves from 10 pear trees (5 from each) in the pear orchard mentioned above. Census for citrus started in late November, 1984 and continued throughout the winter till the end of March, 1985, and for pear the census started in mid-June, continuing till mid-November when defoliation was completely finished. Both censuses were conducted at intervals of 2 weeks. At each census, all the mites on each leaf were counted under a microscope to record the density and stage structure, but for pear only half the area of each leaf surface was observed after mite density had reached a high level in October.

RESULTS

On citrus most hatchings finished in mid-December and it was in mid-March of the following year that hatching was resumed, though a few eggs were observed to hatch during midwinter (Fig. 2A). The developmental zero for the eggs of the non-diapausing strain of the citrus red mite is known to be 8.01°C (FUKUDA and SHINKAJI, 1954). Based on this and the temperature records at Takatsuki and Kyoto, Fig. 5 shows the expected dates for hatching of the eggs oviposited in autumn. There were few differences between the hatching dates forecasted from the temperature records at the two sites, and the figure shows that the eggs laid after mid-November will overwinter and will hatch after mid-March if they survive the winter. This prediction is consistent with the result shown in Fig. 2A, except that there were a few eggs that hatched during midwinter.

There was a tendency that the later the season when the eggs were laid, the greater was their mortality during winter: the mortality rates were 47, 65, and 78% for the eggs collected on Nov. 20, Dec. 6 and Dec. 22, respectively (Fig. 2B). The patterns of mortality and hatching of the eggs collected on Dec. 22 and those collected on Jan. 11 were quite similar (Fig. 2B), implying that the eggs of these two groups would be from the same sample and therefore oviposition would end by mid-December at latest.

Most pear leaves defoliated by early to mid-November so that the eggs collected
Fig. 2. Patterns of hatching (A) and mortality (B) of the eggs of *P. citri* from citrus in Takatsuki. Dates indicate the days when the eggs were collected and numerals in parentheses are the number of eggs tested.

Fig. 3. Patterns of hatching (A) and mortality (B) of the eggs of the non-diapausing *P. citri* population in the Takatsuki pear orchard. Dates indicate the days when the eggs were collected and numerals in parentheses are the number of eggs tested.

Fig. 4. Patterns of hatching (A) and mortality (B) of the eggs of the diapausing population that was artificially introduced from Amagi, Fukuoka to potted pear trees placed in Kyoto. 477 eggs collected on Nov. 14 were tested.

Fig. 5. Dates forecasting the hatching of the eggs which were laid in autumn by the non-diapausing *P. citri* strain, on the basis of the temperature records at Takatsuki (▼) and Kyoto (●) shown in Fig. 1.
from pear twigs should have been laid by that time. Ninety-three per cent of the eggs collected in early November and 62% of those collected in late November hatched by mid-December (Fig. 3A). The rest all died during winter and there were no eggs that hatched in spring of the following year (Fig. 3B). To confirm the survival of the eggs under the natural conditions on pear trees, eggs that overwintered on pear trees were collected on March 10, 1985. Of the 500 eggs collected, none survived, confirming that nondiapausing eggs on pear cannot successfully overwinter.

Compared with the mortality rate of the non-diapausing eggs, that of diapausing eggs was much lower (Fig. 4B), only 15%, and hatching was concentrated in a brief period in early to mid-April (Fig. 4A).

Figures 6 and 7 show the changes in population density and stage structure on citrus and pear, respectively. On citrus mite density declined continuously throughout the winter. The density at the end of March was only 1/4 of that in late November. During the period from mid-December to mid-March when no reproduction occurred, the proportion of adults and immatures decreased respectively to 43% and 32% of the proportions observed in mid-December, whereas the proportion of eggs increased, suggesting that the mobile stages are more liable to winter mortality than the eggs. In late March the proportion of immatures began to increase, whereas that of eggs began to decline, showing hatching was resumed at this time. This was consistent with the result for the pattern of hatching shown in Fig. 2A.
DISCUSSION

The present study shows that the non-diapausing population in the Takatsuki pear orchard cannot maintain itself throughout the winter. This is not simply because the non-diapausing eggs are unable to resist the coldness or drought during midwinter, because on citrus where food resource is available throughout this season all stages including eggs survive, though mortality is high. On pear most eggs laid in late autumn hatch before midwinter and the larvae hatched eventually die of starvation. Although some individuals were observed to migrate to the ground cover vegetation beneath pear trees, they also eventually died, as the weeds disappeared during winter.

A question arises, then, why the non-diapausing eggs on citrus survive the winter, whereas those on pear die. This seems attributable to the difference in season when the overwintering eggs are laid. Oviposition on citrus continues longer than on pear, till early or mid-December, whereas on pear it ceases by mid-November because most leaves defoliate by that time and therefore adult females can no longer survive. Thus, the development of the eggs on pear is at a more advanced stage than on citrus when winter comes, and it is thought that the former are more vulnerable to winter mortality. In fact, most eggs from pear which died were advanced in their embryonic development and in many larvae were ready to hatch. It should be mentioned that no ecological differences exist between the non-diapausing populations from citrus and pear (see Morimoto and Takafuji, 1983) and the two populations are completely compatible with each other (see Takafuji and Fujimoto, 1985).

However, unlike in the Takatsuki pear orchard, in Okitsu in the southern part of Shizuoka Prefecture in central Honshu, Shinkaji (1961 b) reported that non-diapausing eggs continue to hatch until mid-April. In that area where the winter is milder than in Takatsuki, pear leaves remain on trees until January, thereby enabling females to extend their oviposition later into the autumn, just as on citrus. It may be possible, therefore, that the population may maintain itself on pear, if pear buds are available as food for the larvae which hatch in early spring.

The present study confirms that the non-diapausing population on pear in the intermediate altitudinal zones of Japan consists of immigrants from other tree species (cf. Takafuji and Morimoto, 1983), although the host trees from which the immigrants originate were not determined. Within the Experimental Farm, besides citrus, the host tree where the citrus red mite was observed throughout the winter was Ilex crenata Thunb. which was planted as a hedge around a building near the pear orchard. It is, therefore, highly likely that citrus and/or I. crenata are the source of the immigrants.

REFERENCES


Winter Survival of Non-Diapausing *P. citri*  


