Reproductive Interference between *Panonychus mori* YOKOYAMA and *P. citri* (MCGREGOR) (Acari: Tetranychidae) in Peach Orchards

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The reproductive interference between *Panonychus mori* YOKOYAMA and *P. citri* (MCGREGOR) was studied in peach orchards, where they coexisted. The abundance of the two species differed greatly among individual peach trees, but the seasonal population trends were similar to each other: populations remained at very low densities from May to July, and thereafter began to increase, reaching peaks in October. Ineffective females (females that produced no female offspring), resulting from the interspecific matings between the two species, were observed in both species on the trees where they coexisted. The degree of reproductive interference varied depending on the ratio of the densities of the two species on individual trees, and was higher on *P. mori* by *P. citri* than vice versa. Furthermore, the proportion of females from overwintered eggs of *P. mori* collected from trees with a mixture of the two species was very low. These results seem to partially explain why *P. mori* cannot extend its distribution to lower latitudes where climatic conditions are favorable for the species.

Key words: reproductive interference, mating, *Panonychus mori*, *Panonychus citri*, seasonal occurrence

INTRODUCTION

Interspecific matings have been observed in the arrhenotokous spider mites of the family Tetranychidae under laboratory conditions. In most tetranychid mites, interspecific matings produce no F₁-hybrids (HELLE and VAN DE BUND, 1962; BOUDEREAUX, 1963; GOTOH, 1986; OZAWA and TAKAFUJI, 1987; GOTOH and NOGUCHI, 1990; KUNIMOTO et al., 1991; GOTOH and TAKAYAMA, 1992). For example, OZAWA and TAKAFUJI (1987) reported that the interspecific crosses between *Tetranychus urticae* KOCH and *T. kanzawai* KISHIDA were totally ineffective, and did not affect successful fertilization with a male of the same species. However, matings between closely-related species sometimes produce infertile F₁-females, or produce eggs fertilized with sperm of the other species, though no F₁-females develop from them (BOUDEREAUX, 1963; SMITH, 1975). In such cases, a subsequent intraspecific mating may become ineffective.

Two closely-related *Panonychus* species occur in Japan. *P. mori* YOKOYAMA, which was formerly called the diapausing strain of the citrus red mite, *P. citri* (MCGREGOR) (EHARA and GOTOH, 1992), occurs on deciduous trees such as pear and peach, and overwinters as diapausing eggs on the twigs. The non-diapausing species, *P. citri*, occurs on evergreen trees such as citrus and box throughout the year, and is also found on pear and peach, although

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it does not successfully overwinter on the deciduous trees (TAKAFUJI and MORIMOTO, 1983; TAKAFUJI and FUJIMOTO, 1986; SUN et al., 1988; KUNIMOTO et al., 1993). On the deciduous trees, the two species segregate their geographical distributions: *P. mori* is distributed at higher latitudes and *P. citri* at lower latitudes (SHINKAJI, 1961, 1979). However, they coexist in some areas at intermediate latitudes (TAKAFUJI and MORIMOTO, 1983; SHINKAJI et al., 1986), although their occurrence is often unstable (TAKAFUJI, 1986, 1988).

Interspecific matings between the two *Panonychus* species produce no adult females, showing a complete reproductive isolation between them (TAKAFUJI and FUJIMOTO, 1985; OSAKABE, 1993). However, a proportion of eggs from the interspecific matings are fertilized, and because of this a subsequent intraspecific mating is generally ineffective (TAKAFUJI, 1986, 1988).

The above facts suggest that under the coexistence of the two species, there is a reproductive interference due to the interspecific matings between them (TAKAFUJI, 1986, 1988). However, no evidence has so far been obtained under field conditions, with the exception that the proportion of females from diapausing eggs of *P. mori* was low in a pear orchard with a mixture of the two species (TAKAFUJI, 1988). The present study examines the occurrence of interspecific matings and reproductive interference between the two species in peach orchards where the two species coexisted with different proportions.

MATERIALS AND METHODS

Orchards. Field studies were carried out in 3 peach orchards (PM, PC and MX) in southern Okayama (34°47'N), western Honsyu, where either or both species of *Panonychus* occurred, in order to clarify the degree of reproductive interference between them. Only *P. mori* and *P. citri* occurred in orchards PM and PC, respectively, whereas in orchard MX both species coexisted. The three peach orchards were located adjacently and each consisted of 15–40 peach trees of several varieties. In all the orchards, various pesticides were sprayed to control major insect pests of the peach during the study period.

Population census. Nine, three and six census trees were chosen in orchards PM, MX and PC, respectively. At intervals of about 10 days, five leaves were collected at random from each of four selected branches of each census tree. The leaves were put into paper bags and held inside plastic bags in a portable refrigerator. Only adult females of two *Panonychus* species were counted separately using a dissecting microscope, as the other stages could not be identified by species. The census was carried out from May 17 to October 18, 1993.

Reproductive interference. Adult females of both species were collected from each census tree on September 17 from each orchard, in order to elucidate whether or not they were mated effectively. Females collected were individually transferred onto 1.5×1.5 cm² peach leaf discs in Petri dishes and were allowed to lay eggs for six days. The resulting immatures were reared to the deutonymphal or adult stages, and sexed. Females which produced at least one female offspring were grouped as those which were effectively mated (effective females), whereas females which did not produce any female offspring were grouped as those which were not (ineffective females). Females which did not lay more than five eggs were excluded from the data.

*Sex ratio from overwintered eggs of *P. mori*.* On trees in orchard MX, *P. mori* and *P. citri* coexisted with various ratios in autumn, when diapause was induced in *P. mori*. In order to determine the degree of reproductive interference, diapausing eggs were collected from two

of the six census trees in late November, 1993, as sufficient eggs were not obtained from the others. For comparison, eggs were sampled from two census trees in orchard PM, where only *P. mori* occurred.

In sampling, peach twigs covered with diapausing eggs were cut off. They were kept outdoors in a net cage in the Kasai Experimental Farm of Sumitomo Chemical Co., Ltd., located in Kasai, Hyogo Prefecture. Eight twigs were sampled per tree and cut into small pieces in mid-April, 1994, when all non-diapausing eggs, if any, should have died (see TAKAFUJI and FUJIMOTO, 1986). After removing dead eggs, pieces of twigs with eggs were placed on peach leaf discs and kept in the laboratory at 25°C, 50–60% R.H. and 16L: 8D. The eggs were reared to the deutonymphal or adult stages, and sexed.

RESULTS

Seasonal occurrence of two *Panonychus* species

In orchard PM, populations of *P. mori* remained at low densities from May to early July, and then increased to peaks, mostly in October (Fig. 1A). Populations of *P. citri* in orchard PC remained at extremely low densities until late July, and began to increase in August, showing a rapid increase in September–October (Fig. 1B).

In orchard MX, the densities of the two species and their ratios differed greatly among the trees (Fig. 1C). However, the general population trend of each species was similar to that in orchards PM or PC.

Reproductive interference

Table 1 shows the proportions of ineffective females of the two species collected from individual trees in orchard MX, in comparison with species not coexisting with the other

Fig. 1. Seasonal population trends of two species of *Panonychus* on individual trees in peach orchards (A) PM, (B) PC and (C) MX. In orchards PM and PC, only *P. mori* and *P. citri* occurred respectively, whereas in orchard MX both species coexisted.

Fig. 1 (continued)

species. The degree of reproductive interference varied greatly among the trees. In three of the five trees in orchard MX (Nos. 3, 4 and 5), the proportion of ineffective *P. mori* females was significantly higher than that of *P. mori* females from orchard PM. With *P. citri*, however, the tree No. 2 was the only one that had a significantly higher proportion of ineffective females, as compared with the proportion in orchard PC.

Figure 2 shows the relationship between the proportion of ineffective females of each of the two species, and the ratio of their densities on individual trees. In each species, the degree of reproductive interference tended to increase with an increase in the density of the other species relative to its density. This increase in the degree of interference was more conspicuous in *P. mori* than in *P. citri*, as was shown by a larger slope in the regression line for the former (Fig. 2).

The above results indicated that reproductive interference through interspecific mating could occur in both species, but the interference on *P. mori* by *P. citri* would be more intense than the interference on *P. citri* by *P. mori*.

Table 1. Reproductive interference between two species of *Panonychus* in peach orchard MX, where they coexisted, as compared with that in orchards PM and PC, where *P. mori* and *P. citri* alone occurred, respectively

Orchard	Tree	% ineffective females (n) ^a		No. of adult females per leaf		Ratio of <i>P. citri</i> / <i>P. mori</i>
		<i>P. mori</i>	<i>P. citri</i>	<i>P. mori</i>	<i>P. citri</i>	
MX	No. 1	— ^c	—	0.05	0.10	2.00
	No. 2	6.2 (97)	25.0 (68)**	4.90	1.25	0.26
	No. 3	56.3 (32)**	4.4 (68)	1.25	3.85	3.08
	No. 4	37.5 (16)**	10.9 (64)	0.63	1.73	2.75
	No. 5	20.5 (39)**	13.3 (45)	1.55	1.30	0.84
	No. 6	10.0 (20)	9.5 (42)	0.50	0.90	1.80
PM ^b		4.2 (71)	—	1.01	0.00	—
PC ^b		—	13.7 (73)	0.00	2.10	—

^a Ineffective females are those which produced no female offspring. Column values followed by ** in orchard MX were significantly ($p < 0.01$, χ^2 -test) different from that in orchard PM or PC.

^b Females of *P. mori* and *P. citri* collected from nine and three trees, respectively, were pooled to determine the proportion of ineffective females.

^c —: Mites were absent.

Fig. 2. The proportion of ineffective females of two species of *Panonychus* in peach orchard MX where they coexisted, in relation to the ratio of densities of their adult females. Ineffective females are those which produced no female offspring.

Sex ratio from overwintered eggs of *P. mori*

The proportion of females from overwintered eggs of *P. mori* in orchard MX was significantly lower than that in orchard PM (Table 2). The proportion of females in eggs from mated females of this species is known to be higher than 0.60 (TAKAFUJI and FUJIMOTO, 1985; KUNIMOTO et al., 1991; OSAKABE, 1993). Compared to this potential sex ratio, populations in PM had similar sex ratios, whereas those in MX had much lower values. In MX, the sex ratio was significantly lower on tree No. 3 than on tree No. 2. *P. citri* was more abundant than *P. mori* on tree No. 3, whereas *P. mori* was predominant on tree No. 2. These results confirm that the interference on *P. mori* by *P. citri* occurred, and its intensity depended on their relative densities.

Table 2. Comparison of sex ratios from overwintered eggs of *P. mori* collected in two peach orchards

Orchard	Tree	Sex ratio [$\frac{\text{♀}}{(\text{♂} + \text{♀})}$] ^a
MX	No. 2	0.50 (584) b
	No. 3	0.38 (324) a
PM	No. 4	0.62 (444) c
	No. 8	0.68 (494) c

^a Numerals in parentheses are the number of individuals tested. Column values followed by different letters differ significantly ($p < 0.05$, TUKEY's gap test).

DISCUSSION

This study presents evidence that reproductive interference through the interspecific mating between *P. mori* and *P. citri* occurs under field conditions where they coexisted, as was predicted by laboratory mating experiments (TAKAFUJI, 1986, 1988). The study also supports the finding that reproductive interference tends to be more intense on *P. mori* than on *P. citri*. This is because the first interspecific mating suppresses the effectiveness of the subsequent intraspecific mating to a greater extent for *P. mori* than for *P. citri* females (TAKAFUJI, 1986, 1988). These results suggest that under the coexistence of the two species, a population increase will be suppressed in both species, but more severely for *P. mori* than for *P. citri*. Our present study did not directly elucidate the effect of reproductive interference on their population dynamics, but it was demonstrated by the lowered proportion of females from the overwintered eggs of *P. mori* in the orchard with a mixture of the two species.

The present study also shows that the reproductive interference between the two *Panonychus* species depends on the relative density, which certainly affects the frequency of interspecific mating. There are many factors that may affect the density levels of the mites. A factor is the difference in the susceptibility against some pesticides between the two species (FUJIMOTO and HIRAMATSU, 1995). However, the occurrence of *P. citri* on deciduous hosts such as peach, where they cannot overwinter, depends strongly on whether or not evergreen hosts, such as citrus, exist in the vicinity of the deciduous hosts. Thus, the density level of *P. citri* will be affected by the timing of immigration and the number of immigrants from the evergreen hosts. Observations show that the occurrence of the two species on deciduous fruit trees is unstable in their distribution boundary areas (TAKAFUJI, 1986, 1988), and that each species has often been replaced with the other. The more severer reproductive interference on *P. mori* by *P. citri* seems to partially explain why *P. mori* cannot extend its distribution to lower latitudes, where climatic conditions are favorable for this species. The study also suggests that reproductive interference through interspecific matings may be responsible for the habitat segregation between the two *Panonychus* species, as was theoretically predicted by KUNO (1992).

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