[SHORT COMMUNICATION]

The Overwintering Ecology and Diapause Capacity of *Tetranychus kanzawai* Kishida (Acari: Tetranychidae) in West-Central Taiwan

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INTRODUCTION

The spider mite, *Tetranychus kanzawai* Kishida is a serious pest on a variety of agricultural crops and is most abundant in East Asia (Ehara, 1999), although now it is observed worldwide including South-east Asia, Oceania and North America (Bolland et al., 1998). As in many *Tetranychus* species, *T. kanzawai* undergoes a reproductive diapause mainly induced by short-days and low temperatures. Most populations in Japan, except those from Okinawa, have genetically a very high capacity for diapause and express more than 90% diapause when induced at 15°C (Takafuji et al., 2001, 2003).

In Taiwan, *T. kanzawai* is one of the most common spider mites, occurring on a variety of host plants (Ho, 2000). Our previous study (Takafuji et al., 2005) showed that Taiwanese *T. kanzawai* populations have genetically much diversified diapause characteristics. Many of the populations have a high capacity for diapause, as shown by high diapause percentages if induced in the laboratory, while they are distributed in the subtropics. Herein we studied the overwintering ecology of *T. kanzawai* in west-central Taiwan, to elucidate whether the high diapause capacity shown in laboratory experiments is exerted also in the field of Taiwan.

MATERIALS AND METHODS

Study area

We performed population censuses of *T. kanzawai* in December 2004 and in December 2005 in Minjian, Nantou Province (E120°39', N23°52'; about 200 m in altitude) in west-central Taiwan, to elucidate the overwintering stage and the diapause status of adult females in the field of the subtropics. Due to the low density of the mites at the time of samplings, we could obtain reliable data from only a single population each year: on Dec. 27, 2004 from tea (*Camellia sinensis*) and on Dec. 29, 2005 from cassava (*Manihot esculenta*). Although the two populations were studied in different years, they were distributed only 100 m apart.

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The cassava plants were planted around a tea field (not the one where *T. kanzawai* were collected in 2004).

Overwintering ecology

We sampled host plant leaves where *T. kanzawai* were occurring. They were put into paper bags wrapped with vinyl ones and carried to the laboratory. Immediately we examined the stage structure of the mite populations and the diapause status of adult females under a stereomicroscope. Determination of the diapause status was based on the body color of the females: females having a vivid orange color were judged to be in diapause and dark red ones to be as non-diapausing (see Takafuji et al., 2001, 2003, 2005). However, it is known that the diapause of many individuals of *T. kanzawai* in southern Japan ends by mid-winter (Mochizuki and Takafuji, 1996; Morishita and Takafuji, 1999; Takafuji and Morishita, 2001), although the body color of many of the females remains orange until spring. Therefore, precisely speaking, the proportion of females having an orange body color here obtained in late December indicates the proportion of females that were in diapause (having ended diapause) plus those in diapause. We studied all the mites on 72 tea leaves sampled and those on a half of each of 15 randomly selected cassava leaves, as mite density was much higher on cassava.

Diapause capacity

To elucidate the capacity for diapause, we carried mite samples alive to Japan and they were reared on detached kidney bean (*Phaseolus vulgaris* L.) leaves for one generation at 25°C at 16L8D, to obtain enough adult females for conducting diapause induction experiments. We transferred 8–10 adult females randomly sampled from the stock culture onto each of 12 bean leaves pressed on top of water-saturated cotton in 9-cm Petri dishes (see Takafuji et al. 2001, 2003). We allowed females to lay eggs for 2 days at 25°C-16L8D and then removed them. The offspring on each of 4 out of 12 leaves were reared until adulthood at 15, 18 or 20°C-9L15D to induce diapause. We examined the diapause status of females 8 to 10 days after adult emergence. The diapause status of females was determined in the same manner as above (see Takafuji et al., 2001, 2003).

RESULTS AND DISCUSSION

Figure 1 shows the stage structure in two populations. Both populations consisted of all stages from egg to adult but the population on cassava had a higher proportion of eggs and also a higher proportion of adults. One hundred and 92% of adults were females in the tea and cassava population, respectively. Figure 2 illustrates that the percentage of females having an orange body color was about 5 times larger in the tea population than in the cassava population, showing that the proportion of females that expressed diapause was much larger in the tea population.

While the two populations were close to each other, the inherent capacity for diapause, as expressed by the incidence of diapause under laboratory conditions, differed greatly between them; it was much higher in the tea population than in the cassava population. At 15°C and 18°C the tea population exhibited higher than 90% diapause, while the diapause percentage of the cassava population was about 57% at 15°C and 25% at 18°C (Fig. 3). Either of the

Fig. 1. Stage structure of two populations in west-central Taiwan in late December.

Fig. 2. Proportion of adult females with vivid orange body color and those with dark red body color in two populations in west-central Taiwan in late December. Females with vivid orange color are those that were in diapause and are those in diapause.

populations did not express diapause at all at 20°C. The difference in incidence of diapause with the temperature shows that both populations consist of individuals having various diapause capacities (see Takafuji et al., 1991).

Although the number of populations studied is quite limited, the results obtained in this study confirm that the diapause capacity of the Taiwanese *T. kanzawai* is diversified among populations (Takafuji et al., 2005). Clearly, the cassava population has a lower capacity for diapause than the tea population. We also found that the higher the incidence of diapause induced in the laboratory, the higher the proportion of diapausing females in the field. Similar observations have been reported in Japanese *T. urticae* populations (Takafuji et al., 1991).

The lower diapause capacity in the cassava population is reflected in the higher proportion of eggs and also the higher proportion of non-diapausing (ovipositing) adult females. Many eggs on cassava were fresh and adult females seemed to have matured eggs in their ovaries, showing that oviposition is continuing even in late December in this area. The cassava

Fig. 3. Incidence of diapause at 3 temperatures in two populations collected from west-central Taiwan. Number of adult females tested at each temperature was 210–287.

Fig. 4. Average daily temperature records from late autumn (2005) to early spring (2006) in ChuSan, Nantou (Taiwan) (National Chung-Hsing Univ.) and Makinohara, Shizuoka (Japan) (AMEDAS).

plants in the area had plentiful fresh leaves and the density of mites comprising of all developmental stages was very high, thus the food condition in cassava was very suitable for the development and reproduction of the mites even in late December. While tea is an evergreen host having leaves throughout the year, the physiological conditions of tea leaves in late December seemed to be less suitable as food of the mites than those of cassava. It is known that overwintered adult females move from aged to new leaves in early spring (Osakabe, 1967), implying that the mites prefer fresh leaves to old leaves for oviposition. Thus, the higher proportion of eggs and the lower proportion of diapausing females in the cassava population will result not only from the genetically low diapause capacity of the

population but also from good food conditions, as deteriorated food conditions enhance the expression of diapause in spider mites (eg., Lees, 1953; Gotoh, 1989).

In *T. kanzawai*, genetic diversification exists in host utilization ability (Gomi and Gotoh, 1996; Gotoh et al., 1999; Tajima et al., 2007); for example, most populations that occur on non-tea hosts cannot utilize tea as food. Thus, there are strains that differ in host acceptance or host races in *T. kanzawai*. The clearly different diapause capacities between the tea and cassava populations shown in the present study suggest that gene flow is restricted between them, although they were distributed very close to each other.

Figure 4 shows the temperature records from October to March in the area where the two *T. kanzawai* populations were obtained, in comparison with those in Shizuoka, Japan, a well-known tea-production district. Most females of *T. kanzawai* enter diapause in Japan including populations in Shizuoka area, but their diapause intensity is weak as they do not require any chilling for diapause termination (Mochizuki and Takafuji, 1996). Obviously, the temperature is much higher in west-central Taiwan than in Shizuoka, and winter conditions in the former will never be lethal to the mites. Non-diapausing adult females of *T. kanzawai* are known to survive low temperature conditions (3–5°C) (Osakabe, 1967). Nevertheless, many Taiwanese populations of *T. kanzawai* maintain diapause capacity (Takafuji et al., 2005). This is quite different from *T. urticae* in areas with a warm climate including Taiwan in that the mites have almost lost their diapause capacity (Takafuji et al., 2003). Probably the significance of diapause in Taiwanese *T. kanzawai* will be to adjust their development and reproduction to better food conditions.

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