Effect of Photoperiod and Temperature on the Diapause Termination of the Kanzawa Spider Mite, *Tetranychus kanzawai* Kishida (Acari: Tetranychidae)

Masatoshi MOCHIZUKI¹ and Akio TAKAFUJI²

¹ *Pest Control Laboratory, Department of Tea Agronomy, National Research Institute of Vegetables Ornamental Plants and Tea, Kanaya, Shizuoka 428, Japan*

² *Laboratory of Ecological Information, Graduate School of Agriculture, Kyoto University, Kyoto 606-01, Japan.*

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ABSTRACT

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Reproductive diapause of the adult females of the Kyoto population of *Tetranychus kanzawai* induced under laboratory conditions ended much faster under long-day (16L8D) than under short-day (9L15D). Temperature also played a part; the diapause ended quicker at 20°C than at 15°C. The majority of females did not require any chilling for diapause termination. These results suggested that the diapause intensity of *T. kanzawai* in central Japan was weak and short-days maintained diapause. Overwintering adult females collected from a tea field in Shizuoka gradually lost sensitivity to short-days after December. More than half of the females collected in late December started oviposition within about 10 days when exposed to both short-days and to long-days. This result indicated that the diapause of *T. kanzawai* had ended by mid-winter.

Key words: *Tetranychus kanzawai*, diapause termination, diapause intensity

INTRODUCTION

The Kanzawa spider mite, *Tetranychus kanzawai* Kishida is one of the major pests of tea, fruit trees, vegetables and ornamental plants in Japan. This mite shows a reproductive diapause induced by short-days and low temperatures in autumn, and overwinters as adult females (Osakabe, 1967). Females in diapause are easy to recognize by the change in body color from dark red to bright cinnabar. Reactivated females begin oviposition in early spring, and the density of the mites increases thereafter. Acaricidal control against these reactivated females is effective for preventing a subsequent, rapid population increase in late spring. It is important, therefore, to estimate the time of diapause termination in the field.

A number of studies have been reported on the diapause termination of the two-spotted spider mite, *T. urticae* (see a review by Veerman, 1985). Chilling periods are

needed for some populations to end diapause, while others end diapause without them. The required chilling period duration for diapause termination is known to vary among geographical populations (Lees, 1953; Parr and Hussey, 1966; Gotoh, 1986). Photoperiod also greatly affects diapause termination as well. Long-days enhance the termination, whereas short-days maintain diapause status (Veerman, 1977; Koveos *et al.*, 1993).

With the diapause termination of *T. kanzawai*, only a limited number of studies have been published. Osakabe (1967) showed long-days and high temperatures quickly terminated diapause of females collected from a tea field of Shizuoka (central Honsyu) in mid-December. Uchida (1980) supposed that most overwintering females in a pear orchard in Tottori had terminated diapause by early December, because nearly 90% of the females collected in late December had started oviposition within 20 days under 14 L 10 D at 15°C. The accelerated diapause termination under long-days observed in *T. urticae* implies that it is also the case with *T. kanzawai*: diapause state may be maintained later in the field than previously estimated based on laboratory treatment of long-days. Thus, precise studies are obviously needed on the effects of photoperiod as well as temperature on the diapause termination of *T. kanzawai*. The present study elucidates these effects by using both laboratory- and field-induced diapausing females of *T. kanzawai*, and clarifies the time when the mites end diapause in the field.

MATERIALS AND METHODS

Effects of photoperiod and temperature on diapause termination. The population used here was collected from a tea field in Kyoto city in April 1985 and was maintained on bean leafdiscs (*Phaseolus vulgaris* L.) under laboratory conditions of 16 L 8 D at 20–25°C.

For diapause induction, 20–30 adult females were allowed to oviposit on each leafdisc for 24–48 hr under 16 L 8 D at 15°C or 20°C. Eggs were then reared to the adults under 9 L 15 D at either of the temperatures. Adult females thus reared were maintained under the same photoperiod regime as in the immature stages either for two weeks at 20°C or three weeks at 15°C after adult emergence. Under these conditions, 100% of adult females entered diapause.

In order to elucidate the effect of photoperiod on diapause termination, diapausing females obtained under 9 L 15 D at 20°C were individually transferred onto leafdiscs (1 × 1 cm) and maintained under each of four photoperiod regimen, 9 L 15 D, 11 L 13 D, 13 L 11 D and 16 L 8 D, at 20°C. The mites were observed at 2–7 day intervals for 65 days. Once oviposition had started, they were determined to have terminated diapause.

Effect of temperature on diapause termination was studied by using diapausing females induced under 9 L 15 D at 15°C. The females were individually transferred onto leafdiscs (1 × 1 cm) and maintained under 15°C or 20°C with 9 L 15 D. Observation lasted 48 days. Combined effects of long-days and temperature on diapause termination were also studied. Diapausing females induced under 9 L 15 D at 15°C were transferred to 16 L 8 D at 20°C, in the same manner as mentioned above, and observation lasted 14 days.

Diapause termination in the field. As was shown in *T. urticae* (Veerman, 1977),

sensitivity of diapausing *T. kanzawai* to short-days which maintain its diapause state may be gradually lost. We studied the changes in this sensitivity by periodically collecting females from the field and estimated the time of diapause termination. Twenty to eighty adult females in diapause were collected at 15–30 day intervals from November 1987 to February 1988 from a tea field in Kanaya, Shizuoka Prefecture. These mites were individually transferred to leafdiscs (1 × 1 cm), which were divided into two groups. One was kept under 9L 15D, and the other under 16L 8D at 15°C. Diapause termination was observed in the same manner as mentioned above.

RESULTS AND DISCUSSION

Females subjected under longer day lengths than 13L 11D began oviposition only after 4 to 7 days at 20°C (Fig. 1 A), whereas those under short-days (9L 15D and 11L 13D) required 17 to 18 days until they started oviposition (Fig. 1 A). These results revealed that duration of diapause was shortened under long-days and chilling was unnecessary for them to end diapause.

Diapause termination under short-day (9L 15D) occurred earlier at 20°C than at 15°C (Fig. 1 B). Females began to oviposit within 5 days and more than half of them oviposited by day 12 at 20°C, whereas at 15°C it was after 35 days when half of the females began to oviposit. Start of oviposition was further hastened under long-day (16L 8D) at 20°C (Fig. 1 B), and more than 95% of females oviposited after 10 days.

The field-induced diapausing females collected in mid-November required more than 40 days until 50% of them started oviposition under 9L 15D (Fig. 2 A), whereas only 15 days was necessary under 16L 8D (Fig. 2 B). However, the mites collected in mid-December from the field rapidly started oviposition after 10 days under short-day. Finally, more than half of the females collected in late December oviposited within about 10 days under both short-(Fig. 2 A) and long-day (Fig. 2 B).

Diapause intensity of *T. urticae* has been measured in terms of the duration of chilling period required for diapause termination (Lees, 1953; Parr and Hussy, 1966; Koveos *et al.*, 1993). However, the laboratory-induced females of the Kyoto population of *T. kanzawai* terminated diapause without chilling even under short-days. Such an observation is also made in the Greek strain of *T. urticae*, which ended diapause without being exposed to chilling conditions (Koveos *et al.*, 1993). Although most females of the Kyoto population of *T. kanzawai* enter diapause, the intensity of diapause is thought to be weak.

Veerman (1977) showed that photoperiodic sensitivity of diapausing females of *T. urticae* to short-day which maintained diapause was retained during the first 2.5 months of diapause, and thereafter this sensitivity apparently disappeared. This fact suggests that it is the exact time of end of diapause state when the reactivation pattern under short-days becomes identical to that under long-days. However, the pattern of diapause termination of *T. kanzawai* has been studied so far only under long-days (Osakabe, 1967; Uchida, 1980). It is now evident that the diapausing state of *T. kanzawai* is also terminated faster under long-days as well as at high temperatures, and short-

Fig. 1. Effect of photoperiod and temperature on diapause termination of the Kyoto population of *T. kanzawai*. (A) Diapause-induced females were kept for 2 weeks after adult emergence under 9L15D at 20°C, and then transferred to various photoperiod regimen. (B) Diapause-induced females were kept for 3 weeks after adult emergence under 9L15D at 15°C, and then transferred to 20°C under 9L15D or 16L8D. Numerals in parentheses are the number of individuals tested.

days maintain diapause. Thus, the result of the present study reveals that the time of diapause termination determined in the former studies was estimated earlier than it actually occurs in the field.

The present study confirms that short-days maintain the diapausing state of over-

Fig. 2. Effect of photoperiod (A: 9L15D, B: 16L8D) at 15°C on diapause termination of the adult females of *T. kanzawai* collected in a tea field at Shizuoka during winter. Dates in panels indicate the time of collection of the mites from the field.

wintering *T. kanzawai*, but this effect of short-days is lost in late December. Therefore, diapausing state is maintained until this period. Thus, the study indicates the diapause termination in the field of central Japan begins at the year-end, which is later than estimated in previous studies under long-days. Overwintering females in this area are ready to lay eggs whenever temperature rises, even in mid-winter.

摘 要

カンザワハダニの休眠覚醒に及ぼす日長と温度の効果
望月雅俊（野菜茶試茶栽培部）・高藤晃雄（京都大学農学研究科）

カンザワハダニの休眠覚醒に対する日長と温度の効果，および野外での休眠覚醒時期を調

べた。20℃短日条件 (9 L 15 D) で休眠誘起されたカンザワハダニ (京都市産) の休眠覚醒は、長日条件下 (16 L 8 D) のほうが短日条件下 (9 L 15 D) よりもはるかにはやく進行した。短日条件では 15℃よりも 20℃のほうがよりはやく覚醒が進み、20℃長日条件ではきわめて速やかに覚醒された。覚醒のためには低温処理は全く必要なく、この個体群の休眠は浅いと考えられた。また、冬期に野外 (静岡県榛原郡金谷町) から定期的に採集した休眠雌成虫に対する短日の休眠維持効果は徐々に消失した。12 月末以降に野外で採集した雌成虫を 15℃に移すと、日長条件にかかわらず 10 日以内に 50%以上が産卵を再開し、ほとんどの雌成虫の休眠覚醒は 12 月末までには終了していると考えられた。

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