Genetic Basis for Host Range in
Tetranychus kanzawai KISHIDA
(Acari: Tetranychidae)¹

Koh GOMI and Tetsuo GOTOH²

Laboratory of Applied Entomology and Zoology,
Faculty of Agriculture, Ibaraki University,
Ibaraki 300-03, Japan

(Received 21 January 1997)

(Accepted 2 May 1997)

Key words: *Tetranychus kanzawai*, tea, hydrangea,
host range, hybrids

In order to understand the evolution of host range in phytophagous insects and other arthropods, it is necessary to clarify the genetic traits associated with expansion or reduction of host plant range and the shift to new hosts, especially to analyze whether host range is controlled by a single locus or by interacting loci (FUTUYMA and PETERSON, 1985; SHECK and GOULD, 1993, 1995, 1996). For this purpose, the ability of F₁ hybrids obtained from a cross between two closely related species that differ in their host plants to survive on both parental hosts has been examined in swallowtail butterflies, *Papilio* spp. (THOMPSON et al., 1990), and caterpillars, *Heliothis* spp. (SHECK and GOULD, 1993). These studies showed that larval performance on hosts was related to dominant autosomal traits. However, a detailed analysis of the effect of genetic factors on the performance on hosts by hybrids is not available for these insect species, because it has been difficult to obtain F₂ offspring and/or because the sex of larvae which died could not be determined.

The kanzawa spider mite, *Tetranychus kanzawai* KISHIDA, is a polyphagous species that feeds on various plant families. Among its many host plants, tea and hydrangea have special significance for *T. kanzawai*: tea is exploited only by populations collected from tea, while hydrangea is exploited only by populations from hydrangea and pear. This means that differentiation of host plants can be as large among populations of the same species as it is among

closely related species. Furthermore, as there is neither reproductive incompatibility nor reduced hybrid fertility among these mite populations of *T. kanzawai* (GOMI and GOTOH, 1996), genetic factors controlling their performance on host plants are easily analyzed by reciprocal crosses. This is because the two sexes have different genotypes due to haplo-diploid sex determination; i.e., males are haploid and females are diploid. Therefore, *T. kanzawai* is a good candidate for analyzing the genetic factors of host plant evolution. In the present study, we examined the developmental performance of the F₁ and F₂ hybrids obtained from crosses between the tea and hydrangea populations on tea and hydrangea leaves to determine the genetic factors that control performance across different hosts.

MATERIALS AND METHODS

Mites. Two populations of *T. kanzawai* were used: one was collected from tea, *Camellia sinensis* (L.), in Kanaya, Shizuoka, on 19 May 1993, and the other was collected from hydrangea, *Hydrangea macrophylla* (THUNB. ex MURRAY) SER. f. *macrophylla*, in Tsukuba, Ibaraki, on 29 March 1993. The stock cultures were maintained on leaf discs (ca. 25 cm²) of the original host plants. In winter, when wild hydrangea leaves are not available, the mites were reared on hydrangea leaves that had been cultivated in a greenhouse. All experiments were carried out at 25 ± 1°C and 16L-8D according to the methods of GOMI and GOTOH (1996).

Survival of F₁ hybrids on both host plants. To determine (1) the difference in survival rates between female and male progeny obtained from crosses of the tea and hydrangea populations, and (2) whether cytoplasmic factors of parent females are related to the performance of hybrids on both parental hosts, larvae produced from intra- and inter-population crosses were reared on tea and hydrangea leaves. Since the sex of immatures cannot be determined, however, a difference in the survival of the two sexes in hybrids would complicate the analysis of the genetic factors affecting survival on different hosts. To overcome this difficulty, the survival rates of immatures on tea and hydrangea leaves were compared with the survival rates of immatures reared on mulberry leaves, *Morus bombycis* KOIDZ. This was done because the sex ratios of *T. kanzawai* were not noticeably influenced by the

¹ Appl. Entomol. Zool. **32** (4): 638-641 (1997)

² To whom correspondence should be addressed.

Table 1. Numbers of females and males that successfully developed from larvae to adulthood in the tea and hydrangea populations of *T. kanzawai* and their F₁ progeny when reared on tea, hydrangea and mulberry

Cross			On Tea (T)			On Hydrangea (H)			On Mulberry (M)			Statistical test ^b	
♀	×	♂	N ^a	♀	♂	N ^a	♀	♂	N ^a	♀	♂	T vs. M	H vs. M
Tea	Tea		58	41	17	63	0	0	61	45	16	ns	—
Hydrangea	Hydrangea		71	0	0	59	47	12	58	47	11	—	ns
Tea	Hydrangea		156	110	46	162	113	0	170	113	57	ns	*
Hydrangea	Tea		160	118	0	152	110	42	157	117	40	*	ns

^a N is the number of larvae placed on leaf discs.

^b Either a χ^2 -test or FISHER's exact probability test was used for analyzing the difference in survival of each sex (ns: not significant at $p > 0.05$; *: $p < 0.05$).

hosts on which the mites were reared and because more than 95% of immatures could develop to adults on mulberry leaves (GOMI and GOTOH, 1996). These results made it possible to estimate the survival rates of each sex in immatures reared on tea and hydrangea leaves based on sex ratios obtained from mulberry leaves. Female adults which mated with males from either the same or different populations were individually allowed to lay eggs for 5 days on mulberry leaf discs. All newly hatched larvae from the leaf discs were transferred onto leaf discs (ca. 25 cm²) of the same test plant in order to estimate the survival rates of each sex in the offspring produced by each female. Two replicates were used for the intrapopulation cross and four replicates were used for the interpopulation cross.

Determination of genetic factors. To determine the genetic factors related to performance on host plants, virgin F₁ and F₂ females were derived from reciprocal crosses between the tea and hydrangea populations and from backcrosses, and then the survival rates of male progeny produced by these females were determined. This procedure was suitable for gametic analysis, because unmated females produce only haploid male progeny. Thirty hybrid females in the teleiochrysalis stage were randomly selected from each cross and transferred onto a mulberry leaf disc (ca. 25 cm²) without any males. These virgin females were allowed to lay eggs for 5 days and were then removed. Ten newly hatched larvae were randomly selected from the mulberry disc and placed on each of 12 leaf discs of each test plant. All leaf discs were checked daily until adulthood to record the number of survivors.

RESULTS AND DISCUSSION

One hundred percent (58/58) of the offspring from the intrapopulation cross of the mites collected from tea (Table 1, line 1) developed on tea, but none (0/63) survived on hydrangea. Similarly, 100% (59/59) of the offspring from the intrapopulation cross of the mites from hydrangea (line 2) developed on hydrangea, but none (0/71) survived on tea. All of the offspring from both crosses (Table 1) successfully developed on mulberry. These results are in agreement with previous results obtained for this species (GOMI and GOTOH, 1996).

In the tea female × hydrangea male cross (Table 1, line 3), the mortality rate of immatures on the paternal host (hydrangea) was 30.2%, while in the reciprocal cross (line 4), the mortality rate on the paternal host (tea) was 26.3%. These mortality rates were not significantly different from the male ratios (number of males/total number of surviving adults) of the offspring of the same crosses placed on mulberry leaves, which were 33.5% (χ^2 -test, $p = 0.521$) and 25.5% (χ^2 -test, $p = 0.875$), respectively. This shows that male offspring which have only the maternal genome failed to survive on the paternal host. Female hybrids which had both maternal and paternal genomes were able to survive well on both parental hosts, regardless of the direction of the cross (Table 1). This result indicates that no maternal effects, such as a cytoplasmic factor, determine the survivorship on these plants.

As shown in Fig. 1, we assumed the existence of a single dominant gene "T," which allows mites to survive on tea, and another gene "H," which allows normal development on hydrangea; i.e., it was assumed that the mites collected from tea have the "T" gene,

Fig. 1. Survival rates of males produced by virgin *T. kanzawai* females which were obtained from crosses between the tea and hydrangea populations, on tea and hydrangea leaves. T and H indicate the mites collected from tea and hydrangea, respectively, and these are also assumed as the single dominant genes occupying independent loci. VF, virgin females. Either a χ^2 -test or FISHER's exact probability test was used for analysis (observed vs. expected; NS, not significant at $p > 0.05$).

while the mites from hydrangea have the "H" gene. Hence, hybrid females which received nuclear genes ("T" and "H") from both parents would be able to perform well on both parental hosts. Based on this assumption, we calculated the expected rates of survival in male offspring.

The expected and observed survival rates of male offspring (Fig. 1) were analyzed by the χ^2 -test or FISHER's exact probability test. The survival rates of male offspring observed on both tea and hydrangea leaves were not significantly different ($p > 0.05$) from the expected values in all cases. Thus, these results could be explained by the presence of "T" and "H" genes that are responsible for allowing development of the males on their respective parental hosts.

The present study strongly suggests that adaptation to plants which contain harmful secondary chemicals such as tannin in tea (DOWD et al., 1983; TAKEDA, 1994) and hydrangenol in hydrangea (UJIHARA et al., 1995), is controlled by only one gene. In other words, the use of a species with the right genetic traits, such as *T. kanzawai*, has demonstrated the possibility that expansion of host range or host shifts is caused by minor mutations or changes. These findings concerning the genetic traits that determine host range in *T. kanzawai* may help to understand host range evolution in spider mites as well as in insects.

ACKNOWLEDGEMENTS

We thank Mr. M. MOCHIZUKI, National Research Institute of Vegetables, Ornamental Plants and Tea, for collecting the tea population of spider mites used in this study, two anonymous reviewers for their valuable suggestions, and Dr. T. MATSUDA, Ibaraki University, for encouragement.

REFERENCES

- DOWD, P.F., C.M. SMITH and T.C. SPARKS (1983) *Insect Biochem.* **13**: 453-468.
 FUTUYMA, D.J. and S.C. PETERSON (1985) *Ann. Rev. Entomol.* **30**: 217-238.
 GOMI, K. and T. GOTOH (1996) *Appl. Entomol. Zool.* **31**: 417-425.
 SHECK, A.L. and F. GOULD (1993) *Entomol. Exp. Appl.* **69**: 157-172.
 SHECK, A.L. and F. GOULD (1995) *Environ. Entomol.* **24**: 341-347.
 SHECK, A.L. and F. GOULD (1996) *Evolution* **50**: 831-841.
 TAKEDA, Y. (1994) *JARQ* **28**: 117-123.
 THOMPSON, J.N., W. WEHLING and R. PODOLSKY (1990) *Nature* **344**: 148-150.
 UJIHARA, M., M. SHINOZAKI and M. KATO (1995) *Res. Popul. Ecol.* **37**: 249-257.

Mating Behavior of the Cotton Caterpillar, *Diaphania indica* (SAUNDERS) (Lepidoptera: Pyralidae)¹

Kinue KINJO and Norio ARAKAKI

Okinawa Prefectural Agricultural Experiment Station,
Naha, Okinawa 903, Japan

(Received 17 February 1997)

(Accepted 19 May 1997)

Key words: cotton caterpillar, *Diaphania indica*, pyralidae, mating behavior

The cotton caterpillar, *Diaphania indica* (SAUNDERS) (Lepidoptera: Pyralidae), is widely distributed in

Japan, Southeast Asia, India, Netherlands, Pacific Islands, Africa, Oriental and Australian regions, and the USA (PETER and DAVID, 1991 a). The larvae of this insect feed on leaves, flowers and fruits of the Cucurbitaceae family. Application of a synthetic sex pheromone for monitoring purposes and utilization of control methods requires greater knowledge of *D. indica* mating behavior. Although some studies have been conducted on the general life history of *D. indica* (e.g., WANG, 1989; PETER and DAVID, 1991 a, b, 1992), the published information on the mating behavior is scant. In this paper, we report the mating behavior of *D. indica*.

MATERIALS AND METHODS

Insects. Larvae of *D. indica* were collected from leaves of cucumber, *Cucumis sativus* L., in Haebarucho, Okinawa, on 11 September 1996. These larvae

¹ Appl. Entomol. Zool. **32** (4): 641-644 (1997)