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The effect of patch size and persistence of host plants on the development of acaricide resistance in the two-spotted spider mite *Tetranychus urticae* (Acari: Tetranychidae)

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ABSTRACT

Spatial and temporal characteristics of host plants can influence the population biology of the herbivores feeding on them. In this study, I examined the effect of variation in host plant characteristics on the development of acaricide resistance in the two-spotted spider mite *Tetranychus urticae,* a widely distributed agricultural pest. This investigation examined the geographic variation in the degree of resistance to two new types of acaricide, pyridaben and fenpyroximate. From mortality tests at field-level concentrations of the acaricides, many populations collected from fruit trees and roses had a high frequency of resistant individuals for acaricides while almost all populations collected from herbaceous crops had low frequencies of resistant individuals. These results, combined with those from a previous allozyme study, indicate that patch size and persistence of host plants regulate the population structure of the mites including gene flow between populations and, by extension, the development of acaricide resistance.

Key words: Two-spotted spider mite, *Tetranychus*, acaricide resistance, host plant, pyridaben, fenpyroximate.

INTRODUCTION

Tetranychus urticae (green form) is one of the most abundant spider mites and is widely distributed throughout Japan in many agricultural systems. This species is polyphagous and causes damage to crops of many species of agricultural plants, deciduous fruit trees (e.g. apple, pear and cherry), herbaceous plants (e.g. eggplant, soybean and cucumber) and flowers (e.g. carnation, chrysanthemum and crown daisy) (Goka and Takafuji, 1995). The mites have rapidly developed resistance to various acaricides, causing serious difficulty in mite control. Genetic information is useful for predicting the rate of development of resistance and the genetics of

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resistance have been well studied in *T. urticae* (Helle, 1965; Overmeer and Harrison, 1969; Rizzieri *et al*., 1988; Herron and Rophail, 1993). However, most of the reports concern only the mode of inheritance through crossing experiments using a few populations or strains. Evolutionary aspects of the development of acaricide resistance in field populations remain little understood.

In agricultural systems, patch size and persistence of the host plants may regulate the local population biology as well as gene flow between populations of herbivorous pest insects (McCauley, 1987; Grasela and Steiner, 1993). These processes will consequently influence the evolution of insecticide and acaricide resistance (Caprio and Tabashnik, 1992; Roderick, 1996). In this paper, I focus on the effect of variation in host plant characteristics (crop area size and persistence) on the development of resistance to two new types of acaricides, pyridaben and fenpyroximate, in *T. urticae* populations. These two acaricides were released in 1991 in Japan. Both acaricides initially showed high potency for the mites, but resistance to them has developed recently in some *T. urticae* populations (Sasaki *et al*., 1994). Resistance to each of the two new acaricides was considered to be under simple monogenic control according to the results of cross experiments (K. Goka, unpublished data). Here, I investigate the susceptibility to the two acaricides of *T. urticae* populations from various crops. I first classified the host plants into two types: (1) deciduous fruit trees and roses, which are perennials in large fields and (2) herbaceous plants such as eggplants, chrysanthemums and strawberries, which are mostly seasonal crops in smaller fields. This classification was a result of a previous allozyme study (Goka and Takafuji, 1995), which indicated differences in the pattern of genetic constitution of *T. urticae* populations between these two groups of host plants.

MATERIALS AND METHODS

Mite populations

Details concerning the samples used in the present study can be found in a previous report (Goka and Takafuji, 1995). Briefly, mites were collected from 48 deciduous fruit tree orchards and rose gardens and from 42 patches of herbaceous plants, some of which had been grown in vinyl- or glasshouses (see the Appendix in Goka and Takafuji (1995)). Nearly all populations were collected during spring 1993 to autumn 1994.

The total number of acaricide sprayings per site was determined for each sample through a questionnaire for growers.

Acaricides

The acaricides tested were commercial formulations of fenpyroximate (Danitoron®, 5% suspension concentrate) and pyridaben (Sanmite®, 20% wettable powder), which were bought locally. These compounds were suspended in distilled water.

Test concentrations were 200 and 50 mg l^{-1} for pyridaben and fenpyroximate, respectively, which are standard concentrations used by growers.

Test protocol

To assess insecticide resistance, a dipping method, as described in a previous paper (Goka *et al*., 1998), was used. Eight to ten adult females from each population were placed on a bean leaf disc trimmed to 2 cm in diameter and kept under 25°C and 16 : 8 h L : D for 24 h. Dead and inactive individuals were removed from the leaf discs. Leaf discs with active mites were then dipped in the acaricide solutions for 10 s and air dried for a few hours at room temperature. Control leaf discs were dipped in distilled water. All treated and control leaf discs were kept as above.

Mortality of adult females was assessed after 72 h. Mites were scored as being alive if they could walk normally after they were touched with a probe; all others were scored as dead. The data for each test were corrected for mortality in the controls using Abbott's (1925) formula.

RESULTS

Mortality in populations from fruit trees and roses

Many populations showed low mortality for both acaricides tested (Figs 1 and 2), suggesting widespread acaricide resistance. The frequency of resistant individuals for both acaricides seemed to be particularly high in Akita (Nos 15, 16 and 18), Fukushima (No. 24) and Yamaguchi prefectures (Nos 44–47).

Mortality in populations from herbaceous crops

Almost all populations from herbaceous crops were susceptible to both acaricides (Figs 3 and 4). Only one population, from Nara prefecture (No. 22), had $>50\%$ resistant mites.

Frequency of spraying

I examined the relationship between the total number of sprayings and mortality for the two acaricides (Figs 5 and 6). For populations from fruit trees and roses, the total number of sprayings of both acaricides varied from one to six. Resistance developed in populations where acaricide was sprayed more than twice and there was a significant correlation between the two parameters for both acaricides ($r^2 = 0.88$ and $p < 0.01$ for pyridaben and $r^2 = 0.81$ and $p < 0.01$ for fenpyroximate): a higher frequency of spraying was likely to induce a higher frequency of resistant mites for both acaricides.

The total number of sprayings of both acaricides also varied in the herbaceous crop fields. However, no significant correlation ($r^2 = 0.32$ and $p > 0.05$ for pyridaben and $r^2 = 0.31$ and $p > 0.05$ for fenpyroximate) was detected between

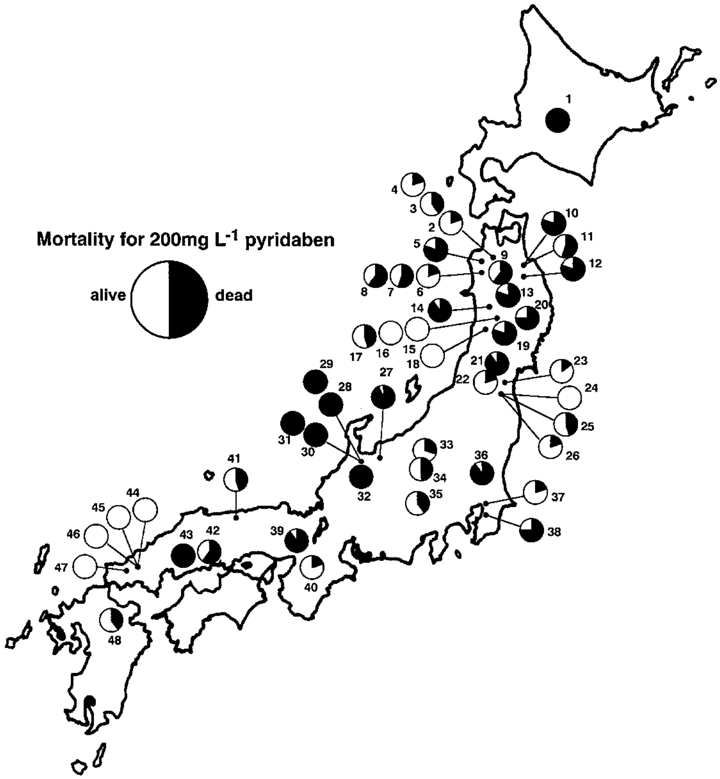

Fig. 1. Geographic variation of susceptibility to the acaricide pyridaben in 48 populations of *T. urticae* collected from fruit trees and rose plants in Japan.

sprayings and mortality for either acaricide. The populations showed high mortality for the acaricides regardless of the number of sprayings. Even the population collected from a field sprayed six times with acaricides showed 100% mortality.

DISCUSSION

Many resistant individuals in the mite populations survived at field-level concentrations of the acaricides on fruit trees and roses, but not in those on herbaceous crops. This indicates that the mite populations on fruit trees and roses are more likely to develop resistance to the acaricides than those on herbaceous crops. One possible explanation is the effect of different local selection pressure, such as spraying frequency. For many pest species, the more frequently a pesticide is used, the more frequently resistance to the pesticide develops (Crow, 1957). In the present study,

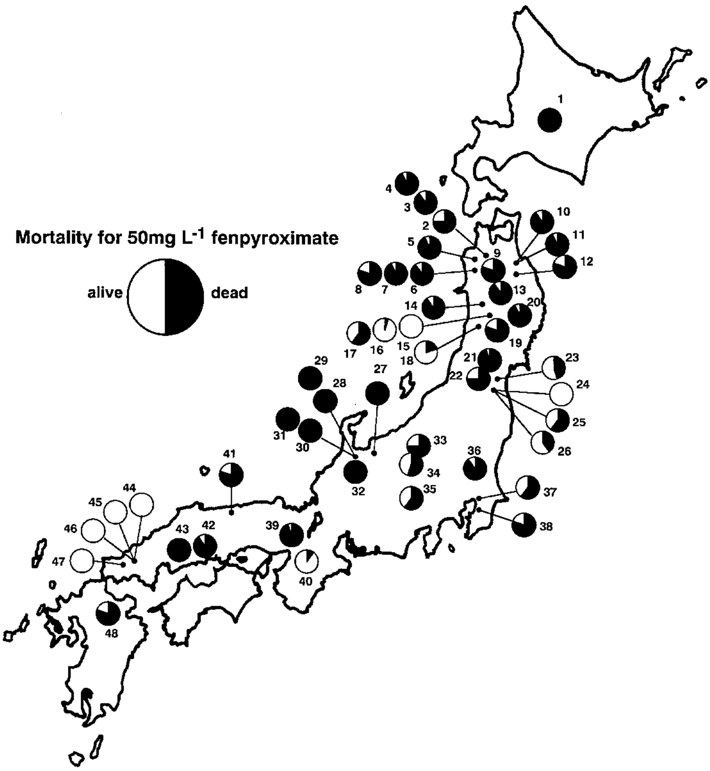

Fig. 2. Geographic variation of susceptibility to the acaricide fenpyroximate in 48 populations of *T. urticae* collected from fruit trees and rose plants in Japan.

that tendency was seen in populations from fruit trees and roses, but not in those from herbaceous crops, suggesting that selective pressure cannot be the sole explanation for the difference in the level of resistance between the two groups of populations.

Another possible explanation is differences in the use of other chemicals on the crops. If there were cross-resistance between the acaricides tested here and other chemicals used, any differences in the latter or the pattern of their use could influence the manifestation of resistance to the acaricides (Georghiou, 1972). However, the acaricides tested showed high performance for control of *T. urticae* populations during the early period of their use, even where there was a high frequency of resistant mites in the present study. For example, the populations in apple orchards in Yamaguchi (Nos 44–47) and Fukushima prefectures (No. 24) showed high susceptibility to fenpyroximate (LC_{50} was approximately 3 mg l^{-1}) and pyridaben (LC_{50} was approximately 20 mg l^{-1}) in 1991 (Sasaki *et al.*, 1994; K. Goka, unpublished data). This result indicates that resistance to the new acaricides

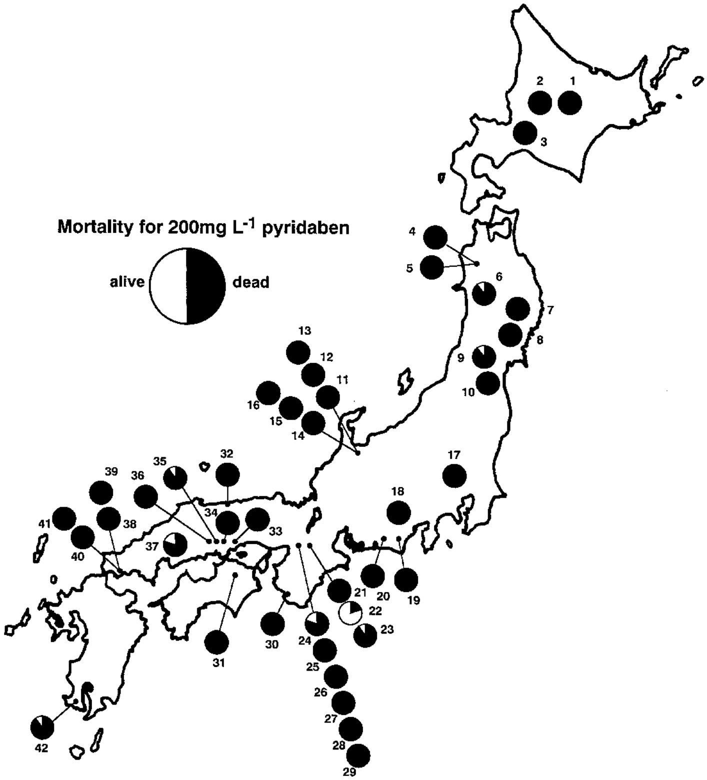

Fig. 3. Geographic variation of susceptibility to the acaricide pyridaben in 42 populations of *T. urticae* collected from herbaceous crops in Japan.

was not due to cross-resistance to any other pesticides used, but developed after growers started using the acaricides.

A third explanation is the difference in patch size and persistence of host plants. Allozyme variation in *T. urticae* populations studied by Goka and Takafuji (1995) suggested differences in gene flow patterns between populations on fruit trees and roses and those on herbaceous crops; these differences are consistent with the development of resistance in the different populations. Mite populations on fruit trees and roses can quickly develop acaricide resistance because they are stable residents, such that gene flow between them would result in the strong likelihood of selection and accumulation of rare genes for resistance. Mite populations on herbaceous crops are unlikely to develop resistance because they are unstable transients and rare genes would be unlikely to be retained for long periods.

Several theoretical and empirical studies have provided evidence that population structures and gene flow should play important roles in the development of

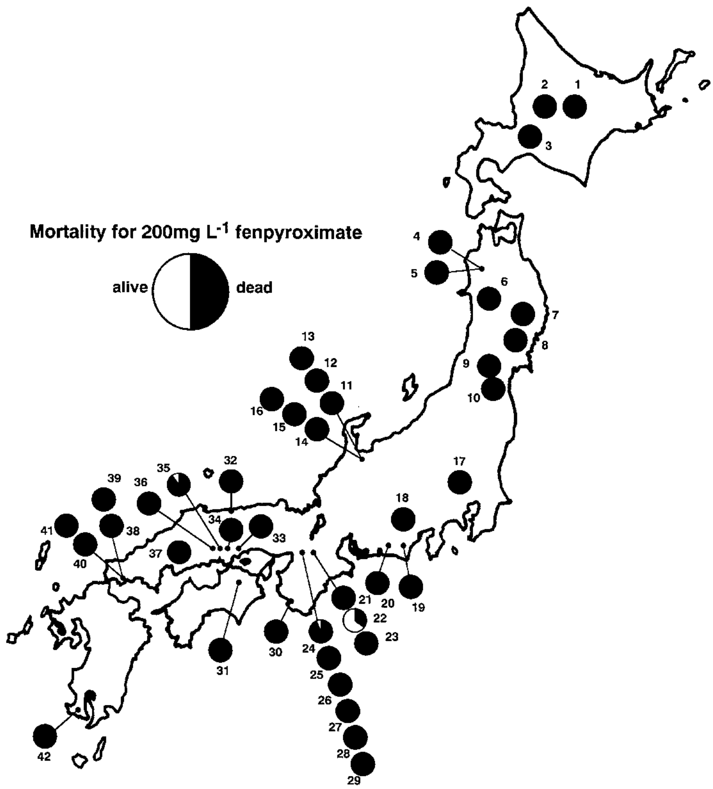

Fig. 4. Geographic variation of susceptibility to the acaricide fenpyroximate in 42 populations of *T. urticae* collected from herbaceous crops in Japan.

insecticide resistance (Tabashnik and Croft, 1982; Roush and McKenzie, 1987; Caprio and Tabashnik, 1992; Dunley and Croft, 1994). These studies indicate that the patch size and persistence of host plants, which will regulate the population structure of pests and gene flow between pest populations, may need to be taken into account in determining the rate of development of resistance in pest populations and in the planning of strategies to contain its spread.

For *T. urticae*, it will be necessary to investigate the dynamics of allele frequencies of allozyme and acaricide resistance in each population for a longer period of time, in order to determine whether the populations on fruit trees and roses are really residents and whether the populations on herbaceous crops are temporal transients. An intriguing problem remains as to how much gene flow exists between populations on perennial hosts and those on herbaceous hosts. If there is considerable gene flow between them, the genes for resistance will eventually spread to populations on herbaceous crops as well.

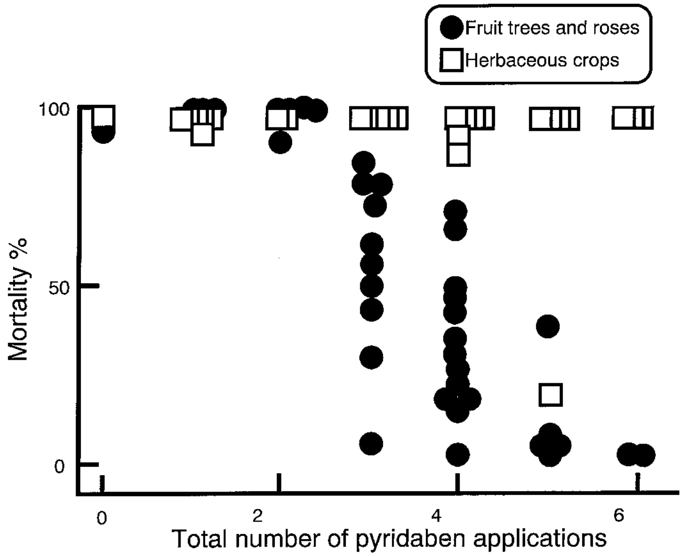

Fig. 5. Correlation between total field applications of 200 mg l^{-1} pyridaben and mortality for each population evaluated.

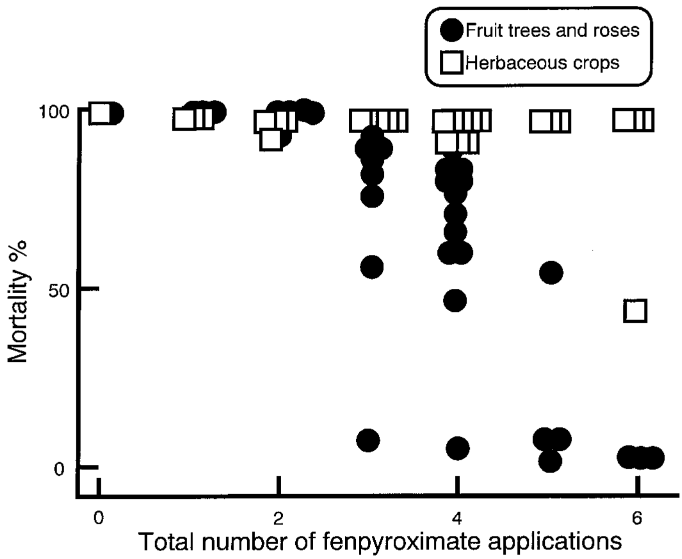

Fig. 6. Correlation between total field applications of 50 mg l^{-1} fenpyroximate and mortality for each population evaluated.

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