CONTROL OF TWO-SPOTTED SPIDER MITE (TETRANYCHUS URTICAE) BY A PREDATORY MITE (PHYTOSEIULUS PERSIMILIS)

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ABSTRACT

A mass rearing technique for the predatory mite, Phytoseiulus persimilis Athias-Henriot, was successfully developed and used in five local Agricultural Extension Centers and by two commercial strawberry growers in Korea. Currently, biological control of the two-spotted spider mite, Tetranychus urticae Koch, by the predatory mite has been successfully implemented in approximately 75 ha of commercial strawberry grown in vinyl greenhouses. T. urticae was effectively controlled by the release of predatory mites at a rate of 3/m². At least two monthly releases were required, both for strawberry crops maturing at the normal time (February or early March) and for early-maturing crops (maturing in December and January). A schedule of abamectin plus the release of the predatory mites was compared with the application of fenazaquin. Abamectin enhanced the control of T. urticae significantly, whereas fenazaquin did not. Fenazaquin was not effective in controlling T. urticae.

INTRODUCTION

In Korea, strawberry is a favorite fruit in winter and spring. Korea’s total production of strawberry ranks seventh in the world. The two-spotted spider mite (TSM), Tetranychus urticae Koch, is an extremely difficult pest to manage on strawberries. The mite has become a major problem, primarily because of the excessive use of pesticides. These kill not only TSM, but also pollinating bees in strawberry greenhouses. Pesticide use results in the development of strains of TSM that are highly resistant to almost all classes of pesticides. In addition, chemical control of TSM is highly restricted in Korea, because of increasing concern over pesticide residues on fruits, especially on strawberries which are consumed fresh without removal of the skin.

Fortunately, the predatory mite, Phytoseiulus persimilis Athias-Henriot, is now available for the control of TSM on strawberry in Korea. This predacious mite was accidentally introduced into Germany from Chili in 1958 (Dosse 1958). From Germany, it was subsequently shipped to other parts of the world, including California (McMurtry et al. 1978).

Strawberries in Korea are cultivated in greenhouses, which keep the temperature above 5°C over the winter (October to April). Such temperatures are favorable for the reproduction and dispersal of P. persimilis. The rate at which P. persimilis develops is a function of temperature, and is described by a straight line over the range of temperatures between 15-30°C (Sabelis 1981). The effect of temperature on the overall predator-prey interaction was studied by Force (1967). He used constant temperatures of 15°C, 20°C, 25°C and 30°C, and obtained excellent control of two-spotted spider mites at 20°C.

Port and Scopes (1981) showed that small numbers of P. persimilis could control TSM on strawberries in walk-in plastic tunnels in southern England. However, it was necessary to reduce overwintering populations of TSM by introducing predators in the autumn. Cross (1984) showed that introductions of predatory mites in March or early

Key words: Phytoseiulus persimilis, Tetranychus urticae, two-spotted spider mite, biological control, strawberry, greenhouse, Korea
April at a rate of one mite per plant were consistently successful. Battaglia et al. (1990) studied the biological control of TSM by *P. persimilis* on strawberry in a greenhouse in the Metapontum area of Italy in 1988-1989.

In 1999-2000, the effectiveness of the phytoseiid predator *P. persimilis* against TSM was investigated in five commercial greenhouses in Korea. The aim of this study was to understand the factors which contribute to the success or failure of biological control of TSM with *P. persimilis* on strawberry in Korea.

**MASS REARING FOR RELEASE**

The National Institute of Agricultural Sciences and Technology (NIAST) in Korea, developed a mass rearing system for *P. persimilis*. It transferred this system to six local Agricultural Extension Centers and two commercial strawberry growers (Table 1). The extension centers used different types of structures to rear *P. persimilis*. One center and a grower used a double-layer vinyl greenhouse; four centers used glass greenhouses equipped with warm-air heaters; the sixth used a double-layer vinyl greenhouse with a cloth mulch; while the second grower used a double-layer vinyl greenhouse with a heater. The rearing space for *P. persimilis* ranged in size from 10 to 333 m². Kidney bean plants were used to rear the TSM population, a food source of *P. persimilis*. They were cultivated from early October to mid-March, and in November and December they were inoculated with TSM. Afterwards, populations of *P. persimilis* were introduced onto the plants in December and January.

Most of the strawberry plants used in this study broke dormancy during December, and were harvested from late February onwards, although one experiment used an early-maturing variety. Leaves of kidney bean plants infested with TSM and *P. persimilis* were randomly placed on the strawberry plants in the greenhouses. The *P. persimilis* included all mobile stages, including nymphs. No chemicals were sprayed on the strawberry plants after the *P. persimilis* were released.

**Results**

The *P. persimilis* were reared in either double-layer vinyl greenhouses or glasshouses (Table 1). Most of the glasshouses had problems of low relative humidity (RH) and low temperature. The vinyl greenhouses had a higher RH but a higher incidence of disease in the kidney bean plants, the host plants for TSM. In addition, the inoculation of *P. persimilis* was delayed in some greenhouses because of the poor heating system. The *P. persimilis* could not be released into three greenhouses, two of which had warm-air heaters, because of plant damage from cold, a low density of TSM, or diseases in the host plants.

<table>
<thead>
<tr>
<th>AEC* &amp; farmers’ greenhouses</th>
<th>Facility for rearing</th>
<th>Rearing problems</th>
<th>Rearing area (m²)</th>
<th>Area (ha) released</th>
</tr>
</thead>
<tbody>
<tr>
<td>AEC 1</td>
<td>Double-vinyl greenhouse with boiler</td>
<td>Low temperatures</td>
<td>100</td>
<td>33.5</td>
</tr>
<tr>
<td>AEC 2</td>
<td>Glasshouse with boiler</td>
<td>Low humidity and temperatures</td>
<td>233</td>
<td>12</td>
</tr>
<tr>
<td>AEC 3</td>
<td>Glasshouse with boiler</td>
<td>Low humidity and temperatures</td>
<td>200</td>
<td>7.3</td>
</tr>
<tr>
<td>AEC 4</td>
<td>Glasshouse with inefficient boiler</td>
<td>Low humidity, and cold damage to plants</td>
<td>60</td>
<td>0</td>
</tr>
<tr>
<td>AEC 5</td>
<td>Glasshouse with boiler</td>
<td>Low density of <em>T. urticae</em></td>
<td>10</td>
<td>0</td>
</tr>
<tr>
<td>AEC 6</td>
<td>Double-vinyl greenhouse with cloth mulch</td>
<td>Plant diseases from high humidity</td>
<td>33</td>
<td>0</td>
</tr>
<tr>
<td>Farmer A</td>
<td>Double-vinyl greenhouse with heater</td>
<td>Low temperatures</td>
<td>233</td>
<td>10.8</td>
</tr>
<tr>
<td>Farmer B</td>
<td>Double-vinyl greenhouse with warm-air heater</td>
<td>Clumping of mite population</td>
<td>333</td>
<td>10</td>
</tr>
</tbody>
</table>

* AEC: Agricultural Extension Centers
EFFECTIVENESS OF
THE BIOLOGICAL CONTROL

Release of *P. persimilis* for control of low densities of TSM for normal cropping season (from late February)

The numbers of TSM were kept to a low level (3.4/m^2) until the fruit were harvested. *P. persimilis* were released at the rate of 1.5/m^2 on February 26, and 3/m^2 on March 3 and March 10 (Fig. 1). Good control was achieved if the *P. persimilis* were released while populations of TSM were still low, before their number increased. Proper timing of the release, and numbers released, varied according to the density of TSM, the environmental conditions such as temperature and humidity, and the growth stage of the strawberry plants.

Control is more effective if the predatory mites are released early in the growing season. Waite (1988) reported that *P. persimilis* gave effective control of the pest when it was released onto strawberry with low levels of TSM infestation in south-east Queensland, Australia. Bonomo *et al.* (1991) also reported that releases of *P. persimilis* gave effective control of TSM, and that it was essential that the predator be released when the density of the pest was low (1-2 per leaf). Spicciarelli *et al.* (1992) recommended that phytoseiid mites give good control of TSM, if one mite is released per plant when the infestation of TSM has reached two individuals per leaf, and about 30% of the leaves are infested.

Release of *P. persimilis* for control of low densities of TSM on early crops of strawberry

The population density of TSM on strawberry plants grown for early harvest in a vinyl greenhouse were < 0.1 mites/leaf in April, even after two releases of three *P. persimilis/m^2* in December and January (Fig. 2). However, TSM increased up to nine mites per m^2 in the control plot. Numbers in the control plot fell to almost zero after spraying with abamectin. Strawberry are usually harvested from February to May, but a number of growers are producing early crops for export to Japan, with a harvest beginning in December. For an early harvest, strawberry should be grown at a consistently high temperature. However, high population levels of TSM can develop very early on strawberries grown in this way.

Release of *P. persimilis* after spraying miticides for control of high densities of TSM

If there is a high population density of TSM,
the release of \textit{P. persimilis} is more effective if numbers of TSM are reduced by a chemical spray. Spraying with abamectin in January, and the release of three \textit{P. persimilis}/m\textsuperscript{2} in February, reduced the numbers of motile TSM per leaf to less than 1.0 in April. This indicates that the chemical application of TSM can be successfully integrated with biological control. It seems that after about one month there were no hazardous residues from the abamectin to harm the \textit{P. persimilis}.

Other pesticide sprays could also be combined with the predator. The application of foliar sprays of chlorpyrifos, malathion, endosulfan, or cypermethrin, one week before or one week after the introduction of \textit{P. persimilis}, did not eliminate the predator, and resulted in successful biological control (Cross \textit{et al.} 1996). Chlorpyrifos and malathion were also successful, but a longer time was needed after spraying before the predator was introduced. Trumble and Morese (1993) reported that the best economic returns were generated by abamectin in combination with \textit{P. persimilis}.

Release of \textit{P. persimilis} to control high densities of TSM late in the cropping season

The population densities of TSM per leaf increased to 11.3 in February and 33.3 in March, while the percentage of leaves infested with TSM increased from 36.7\% in December to 71.5\% the following March (Table 2). Pickel \textit{et al.} (1996) recommended inoculative releases (i.e. initial releases of a small number of predators) of \textit{P. persimilis} when TSM are first found in the crop. However, the grower in the current study released \textit{P. persimilis} too late, by which time TSM had already reached a high density. The outbreak of TSM may have been caused by low humidity in May, when the weather was hot and dry. \textit{P. persimilis} needs a RH > 60\% to survive, particularly at the egg stage.

Release of \textit{P. persimilis} after biological control was interrupted by the application of a toxic chemical

The most common reason for the failure of the biological control of TSM is the application of nonselective pesticides. \textit{P. persimilis} is very susceptible to almost all chemical pesticides. When \textit{P. persimilis} was released at the rate of 1.5/m\textsuperscript{2} in February and 3/m\textsuperscript{2} in March, the crop was then sprayed with fenazaquin. This pesticide seems to be toxic to \textit{P. persimilis}, and the population densities of TSM rose to 13.8/leaf in April (Fig. 4). Population densities of TSM then fell after spraying with milbemectin later that month. Subsequently, the grower stopped using \textit{P. persimilis} and sprayed chemicals instead.

Many growers who have not had any experience of using predatory mites are doubtful

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure2.png}
\caption{Control of TSM (\textit{T. urticae}) by \textit{P. persimilis} on early crop of strawberry in vinyl greenhouse. The control plot was sprayed with abamectin when the population of TSM rose to high levels.}
\end{figure}
Table 2. Control of TSM (T. urticae) on strawberry in vinyl greenhouse by *P. persimilis*, released when numbers of TSM were high

<table>
<thead>
<tr>
<th>Date</th>
<th>TSM eggs/leaf</th>
<th>No. of TSM</th>
<th>% of leaves infested with TSM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dec. 28, 1998</td>
<td>2.3</td>
<td>6.0</td>
<td>36.7</td>
</tr>
<tr>
<td>Feb. 25, 1999</td>
<td>11.3</td>
<td>36.5</td>
<td>70.0</td>
</tr>
<tr>
<td>March 10, 1999</td>
<td>33.3</td>
<td>52.0</td>
<td>71.5</td>
</tr>
</tbody>
</table>

* P. persimilis were released at a rate of 3/m² on February 5, 6, and 23.
whether *P. persimilis* is an effective control agent against TSM. As the resistance of TSM to chemicals such as fenazaquin increases, TSM becomes able to survive chemical applications. However, natural enemies, including *P. persimilis*, are also highly susceptible to these chemicals.

**CONCLUSION**

It would appear that *P. persimilis* can give good control of two-spotted spider mite on strawberry crops, particularly if the predator is introduced early in the cropping season when numbers of TSM are still fairly small. If it is introduced into dense populations of TSM, the control effect is limited. In this situation, it is best to spray a miticide to reduce the numbers of TSM. If abamectin is used, or foliar sprays of chlorpyrifos, malathion, endosulfan or cypermethrin, *P. persimilis* can be introduced a week after spraying with no harmful effects on the predator. Other pesticides may need a longer waiting period after spraying. One study found that a combination of abamectin and *P. persimilis* was the most cost-effective way of controlling TSM in greenhouses. However, pesticides must be selective, because *P. persimilis* is susceptible to almost all chemical sprays.

**REFERENCES**


