[SHORT COMMUNICATION]

Infestation of *Tyrophagus similis* Volgin (Acari: Acaridae) on Spinach during the Seed Germination Period

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INTRODUCTION

The acarid mite *Tyrophagus similis* Volgin often damages spinach (*Spinacia oleracea* L.) (van den Bruel, 1940; Ippolito and Triggiani, 1988; Nakao, 1989). In recent years, it has caused serious damage to greenhouse spinach in the cooler months in Japan (Kasuga and Amano, 2000; Nakao, 1989). The mites initially increase in number on or in cultivated soils rich in organic matter, then invade the spinach buds and feed on the young leaves (Kasuga and Amano, 2003). As the plants grow, the damaged leaves begin to show small holes and deformation.

*Tyrophagus similis* may also damage spinach seed during germination, but this damage has been disregarded thus far. If the germinating seed is strongly affected by *T. similis*, control measures to prevent damage will be needed. The aim of this research was to clarify the effect of *T. similis* on spinach growth during the germination period in order to develop an effective strategy for managing soil-inhabiting *Tyrophagus*. In addition, to predict damage on the basis of the number of mites in the soil, the relationship between the number of mites in the soil and in the seed was analyzed from field data.

MATERIALS AND METHODS

We investigated infestation by *T. similis* on spinach during seed germination in two greenhouses (A and B) in Koshigaya, Saitama Prefecture, central Japan (35°53'N, 139°50'E) from December 1997 to May 1998. The greenhouses were each 50 m×5.4 m and had no heating or cooling facilities. Spinach crops were simultaneously raised in the two greenhouses. In these two greenhouses, spinach crops were grown on andsol (volcanic ash
soil) containing rice husk compost. Three spinach cultivars were grown during the survey period: ‘Atlanta’ was sown on 28 November 1997, ‘Mistral’ on 27 February 1998, and ‘Active’ on 24 April 1998. The greenhouses and cultivation methods are described in our previous paper (Kasuga and Amano, 2003).

Fifteen soil samples of 200 cm$^3$ were taken with a cubic metal sampler (100 cm$^3$; 5 cm long×4 cm wide×5 cm high) from each greenhouse on 5 December 1997, 6 March 1998, and 1 May 1998 (1 week after sowing), when seeds were germinating. The samples were put into plastic bags and transported to the laboratory inside opaque plastic containers without direct exposure to daylight. Spinach seeds were taken from the soil samples, and the mites on the seeds were counted under a stereomicroscope. Symptoms of damage to seeds were recorded at this time. Mites in the soil were extracted in a Tullgren funnel with a 40-W bulb over 3 d and counted under a stereomicroscope. A Student’s $t$-test ($P<0.05$) was used to compare the number of mites in the soil between greenhouses, and regression analysis ($P<0.05$) was applied to test the relationship between the numbers of mites in the soil and on the seed.

Ten quadrats containing 75 seeds per quadrat (5×5 sowing points×3 seeds per point) were established in each greenhouse, and the success of germination was estimated by counting the number of plants in each, 1 or 2 weeks after sampling. The rates of undeveloped plants (=proportion of undeveloped plants of 75 plants×100%) were arcsine-transformed and then compared between the two greenhouses using a Student’s $t$-test ($P<0.05$).

The soil temperature at a depth of 10 cm was measured on the day of sampling. Six thermometers were installed in the greenhouse soil at about 2:00 p.m. Tukey’s HSD multiple-comparison test ($P<0.05$) was used to compare the temperatures on each survey day.

RESULTS AND DISCUSSION

*Tyrophagus similis* damaged germinating spinach seeds. Mites in the soil were thought to have invaded the germinating seeds and fed on their embryos and albumen. As a result,

<table>
<thead>
<tr>
<th>Sampling date</th>
<th>Greenhouse</th>
<th>No. of mites per 200 cm$^3$ of soil (Mean±SE)</th>
<th>% undeveloped plants (Mean±SE)</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 Dec 1997</td>
<td>A</td>
<td>3.5±0.71 a</td>
<td>15.5±2.29 a</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>61.0±17.40 b</td>
<td>25.2±1.96 b</td>
</tr>
<tr>
<td>6 Mar 1998</td>
<td>A</td>
<td>11.7±2.19 a</td>
<td>22.0±0.83 a</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>37.5±10.91 b</td>
<td>27.5±1.65 b</td>
</tr>
<tr>
<td>1 May 1998</td>
<td>A</td>
<td>16.7±2.58 a</td>
<td>25.1±1.62 a</td>
</tr>
<tr>
<td></td>
<td>B</td>
<td>14.4±3.72 a</td>
<td>25.2±1.63 a</td>
</tr>
</tbody>
</table>

Fifteen soil samples were taken from each greenhouse to evaluate mite density. Means followed by the same letter in each row on each date are not significantly different ($P<0.05$; $t$-test). Ten quadrats containing 75 seeds per quadrat were established in each greenhouse to estimate the percentage of undeveloped plants. Plants were counted 1 or 2 weeks after sampling. Percentages followed by the same letter in each row on each date are not significantly different ($P<0.05$; $t$-test after arcsine transformation).
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young roots and buds were injured, and some plants did not develop. On 5 December 1997 and 6 March 1998, the number of mites in greenhouse B was significantly greater than that in greenhouse A ($P<0.05$), and the percentage of undeveloped plants in the former was also significantly greater ($P<0.05$) (Table 1). In contrast, the number of mites and the percentage of undeveloped plants on 1 May 1998 did not differ significantly between greenhouses ($P>0.05$). These results suggest that mites affected the number of growing plants. On 5 December, the number of growing plants in greenhouse B was approximately 10% less than

![Graphs showing relationship between numbers of mites and on seed](image)

**Fig. 1.** Relationship between the numbers of mites in the soil and on the seed. There was a significant relationship ($P<0.05$) on all three dates.
that in greenhouse A. This result confirmed considerable damage by *T. similis* during seed germination.

The relationship between the number of mites in the soil and the percentage of undeveloped plants differed each day (Table 1). On 5 December, only 0.4±0.25 (Mean±SE) mites and very little damage were observed on the spinach seeds in greenhouse A, but 15.5% of the plants failed to develop (Table 1). Because no other disease or insect damage was observed on the spinach during the seed germination period on any sampling dates, some other factors, such as physiological or/and physical factors, probably also affected the seeds. It appears that some factor other than *T. similis* differed between the three survey dates, accounting for the differences found in the relationship between the number of mites and the percentage of undeveloped plants each day.

There was a significant relationship between the number of mites in the soil and that in the seeds on all three dates (*F*=56.2261, *df*=21, *P*<0.001 for 5 December; *F*=7.6331, *df*=14, *P*=0.0161 for 6 March; and *F*=24.0815, *df*=19, *P*<0.0001 for 1 May) (Fig. 1). These results suggest that mite numbers on the germinating seeds increased as those in the soil increased. However, the regression equations differed each day, rendering it difficult to predict the number of mites on seeds on the basis of the number in the soil (Fig. 1). The soil temperatures were 22.4±1.58 (Mean±SE) °C on 5 December, 16.3±0.49°C on 6 March, and 22.0±0.22°C on 1 May; that on 6 March was significantly lower than those in December and May (*P*<0.05). Thus, temperature probably affected the movement of mites to seed; low temperature may have hindered the activity of the mites.

To prevent damage by *T. similis* during seed germination, monitoring and control of mites in the soil before sowing are important. As direct counting of *T. similis* numbers in soil is difficult, the Tullgren funnel (e.g. Aoki, 1973; Krantz, 1978) or acarid bait trap (Kasuga et al., 2005) might be useful for monitoring numbers. Kasuga and Amano (2003) reported that the *T. similis* population in the soil of a spinach greenhouse remained low during the hot season, increased rapidly in the autumn, then remained high during the cool season. Thus, the *T. similis* population should first be monitored in early autumn, between the harvest of the preceding crop and the sowing of the next. If a large number of mites is found in the soil before sowing, the application of acaricides to the soil or heat treatment (e.g. hot water or steam) of the soil will be necessary to prevent damage by *T. similis* during the seed germination period.

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REFERENCES

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