エンバク品種「たちいぶき」の夏播き栽培による後作サツマイモのネコブセンチュウ害抑制

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Suppression of root-knot nematode damage to succeeding sweet potato by summer-sown cultivation of an oat variety, “Tachiibuki”

Yasushi Tateishi¹, Zen-ichi Sano¹², Hideaki Iwahori¹, Kenta Uesugi¹, Masaaki Katsura¹ and Mitsuru Gau¹

Reproduction of four populations of Meloidogyne incognita on ten oat varieties was examined in a greenhouse. Eggmass numbers produced on oat roots inoculated with 500 J2 were counted. Eggmasses of all nematode populations were present on all oat varieties but “Tachiibuki” had the lowest number (1.8 - 1.8 eggmasses / root system). Summer-sown cultivation of four early forage oat varieties sown in September and a fallow treatment were examined in a field infested with M. incognita and M. arenaria. The final / initial population density of J2 (Pf / Pi) in December for varieties “Haeibuki”, “Super Hayate Hayabusa”, “Tachiakane”, “Tachiibuki” and the fallow were 36.5, 34.7, 23.9, 1.9 and 0.2, respectively. Yield of succeeding sweet potato planted in May of the next year and harvested in September was highest in the plot that was previously cropped with the variety “Tachiibuki”, and in the “Tachiakane” plot which also received a nematicide treatment (1.5% a.i. fosthiazate, 20 kg / 10 a) before planting. Sweet potato storage roots from the “Haeibuki”, “Super Hayate Hayabusa” and fallow plots were significantly damaged by root-knot nematode with similar low yields. Damage to storage roots caused by the nematode was significantly reduced by the preceding “Tachiibuki” cropping to an extent similar to the nematicide treatment. Jpn. J. Nematol. 38 (1), 1-7 (2008).

Key words : Avena sativa, cultural control, fall crop, Meloidogyne incognita.

INTRODUCTION

The southern root-knot nematode, Meloidogyne incognita, which causes serious crop yield loss, especially in root crops, is one of the major pests of upland crops in Kyushu, southwestern Japan. Application of nematicides is costly for less profitable upland farming. Therefore, it is important to develop cropping systems to reduce nematode densities. The present cropping systems using known nematode-suppressive plants in Kyushu (Torigoe, 1992)

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are not always practical because their suppressive effect mainly occurs in summer cropping, a period important for farm profitability. No promising nematode-suppressive plants for fall, winter, and spring cropping in Kyushu have yet been found. Furthermore, the general effects of any form of cropping on nematode infestation during these seasons have not been sufficiently examined.

Oat (Avena sativa) is an important gramineous crop for forage and green manure in Japan, and has been cultivated as a winter crop using a conventional cultivation technique referred to as “fall-sown cultivation”. Recently, cultivation of oat as a fall crop using another cultivation technique referred to as “summer-
sown cultivation” has spread in warm areas of
Japan. Cultivation of oat in late summer to early
winter is considerably advantageous because it
can be applied to the vacant cropping period in
fall. Although breeding of early forage oat vari-
eties suitable for summer-sown cultivation has
been promoted (Katsura, 1999), there is a con-
cern that the warm climatic conditions prevail-
ing in Kyushu in fall might encourage nematode
infestation of summer-sown oat.

In the present study, we first examined in a
greenhouse the reproduction of *M. incognita* on
ten oat varieties, including “Tachiibuki” bred in
Japan (Katsura et al., 2001). Second, we exam-
ined the effect of summer-sown cultivation of
“Tachiibuki” and three other varieties in the
field. We surveyed the population density of
root-knot nematodes and the damage to succeed-
ing sweet potato cultivated in the same plot. In
the field study, a fallow treatment and a nematic
dide treatment were included as controls.

**MATERIALS AND METHODS**

Greenhouse test:

Single eggmass populations of *M. incognita*
collected from Nishigoshi (Kumamoto),
Miyakonojo (Miyazaki), Mashiki (Kumamoto),
and Tsukuba (Ibaraki), Japan, were tested as
races SP1, SP2, SP3, and SP4, respectively. Each
race has different pathogenicity to sweet potato
cultivars bred in Japan (Sano and Iwahori, 2005).
Each population was propagated for two to
three months on tomato variety “Pritz” in pots
under the greenhouse condition described below.
An aqueous suspension of the second-stage
juveniles (J2) hatched from eggmasses obtained
from the tomato roots was used as inoculum.

Ten oat varieties shown in Table 1 were
tested. Seeds of oat were obtained from the
Laboratory of Pasture Plant Breeding at the
National Agricultural Research Center for
Kyushu Okinawa Region, Koshi, Kumamoto. On
June 25th, 2003, seeds of oat varieties were sown
in polyethylene pots (9 cm in diameter) filled
with 270 ml of soil prepared by mixing equal
volumes of autoclaved Melanudands soil and
commercially available nursery soil (nitrogen : 
phosphorus : potassium = 0.25 : 1.1 : 0.3 g / l).
The pots were placed in a greenhouse at an aver-
age temperature of 27°C (24 - 30°C). After four
weeks, inoculum of 500 J2 was injected into each
pot containing a single oat seedling.

After 35 days, the oat root systems recov-
ered from the pots were carefully washed. The
root systems were immersed in an aqueous solu-
tion of 0.5% Phloxine B for several seconds to
stain the eggmasses. The eggmasses produced
on each root system were then counted. Each
combination of oat variety and the nematode
population was replicated three or five times.

Field plot test:

Fifteen plots (2.5×2.25 m = 5.625 m²) were
arranged randomly in an experimental field at
Koshi, Kumamoto, Japan, with a natural infesta-
tion of *M. incognita* race SP1 and *M. arenaria*.
The soil was a Melanudands consisting of
15.8% sand, 24.9% silt, and 59.3% clay with
organic carbon content of 9.87%, and pH 6.0.
Nematode infestation in the field had been main-
tained by double cropping of buckwheat for sev-
eral years. A single buckwheat cropping was
also conducted prior to the field plot test from
late April to early August in 2005.

On September 8th, 2005, four varieties
(“Haeibuki”, “Super Hayate Hayabusa”,
“Tachiakane”, “Tachiibuki”) of early forage
oat were sown in rows (nine rows per plot, 25 cm
apart) at 222 grains / m² for summer-sown culti-
vation. Preplant fertilizer was applied in a ratio
of 9.6 (nitrogen) : 10.8 (phosphorus) : 12.6 (potas-
sium) kg / 10 a. On December 12th, 2005, the
above-ground parts of the oat plants were cut
and removed from the plots. The oat stumps
were then immediately ploughed into the plots.
As an evaluation standard for the fall cropping, a fallow treatment was also included. Bare plots during winter and the fallow treatment were managed to keep them weed-free.

Three ridges (64 cm in width, 2 m in length) were raised in each plot and mulched with clear polyethylene film (0.03 mm thick). On May 10th, 2006, a sweet potato cultivar “Kokei 14”, susceptible to the root-knot nematode, was planted as a crop to succeed the oat. Vine terminals of sweet potato, each with five nodes, were transplanted at a distance of 30 cm in each ridge. Preplant fertilizer was applied in a ratio of 2.4 (nitrogen) : 10.2 (phosphorus) : 14.4 (potassium) kg/10 a. On April 25th, 2006, fosthiazate (1.5% a.i.) was applied as a control at a rate of 20 kg/10 a to the “Tachiakane” plot. The sweet potato was grown until September 7th, 2006, to pass the regular cropping period of sweet potato for table use, 120 days. Each treatment was replicated three times.

Soil samples at the start of the oat cultivation were collected at randomly-selected four points from the plowed soil of the plot (0 to 10 cm-deep) using a shovel (approximately 50 g of soil/6×15 cm blade) and mixed well. The samples at the end of the oat cropping were collected again in the same manner at four points under the stumps (15 to 20 cm-deep) and mixed well. Soil samples during the succeeding sweet potato cropping were collected at three points from the lateral face of the central ridge and mixed well. Nematodes were extracted by three Baermann funnels, 20 g fresh soil for each (60 g in total), for 72 hrs at room temperature. The number of J2 of root-knot nematodes was counted under a microscope.

Root samples were randomly collected from four root systems (0 to 15 cm-deep) at the end of oat cropping, then washed, chopped into small pieces, and mixed well. The eggmasses produced on several grams of root samples were counted as described for the greenhouse test, to estimate a density per one gram fresh root. Ten eggmasses were randomly collected from each root sample. The gelatinous matrix was digested in 20 ml of 0.5% sodium hypochlorite solution in vials for 10 min. The egg concentration in the suspension was measured to estimate an egg density per eggmass.

Four plants of sweet potato were harvested from the central ridge of each plot. Every storage root that exceeded 50 g was weighed as the yield. All storage roots with no or only slight damage, e.g. longitudinal cracks, subcortical lesions, and constriction, related to nematode infection, were evaluated as marketable.

Data analysis:

Data were subjected to one-way ANOVA, followed by a Tukey-Kramer test for multiple comparisons of the means, using JMP 5.0.1j computer software (SAS Institute Japan).

RESULTS

Reproduction of *M. incognita* on 10 oat varieties in the greenhouse test:

Differences in the numbers of eggmasses were observed among the varieties (Table 1). The number on the oat variety “Tachiibuki” was consistently lowest among the tested varieties across the four nematode populations. Especially the number for the Nishigoshi population of “Tachiibuki” was significantly lower than that on other varieties except for “Saia”.

Population densities of root-knot nematodes J2 in the field plot test:

For summer-sown cultivation of the early forage oat variety, the final population density of J2 on “Tachiibuki” was significantly lower than that on other varieties, although the lowest density was observed for the fallow treatment (Table 2). The final population / initial population (Pf / Pi) for varieties “Haeibuki”, “Super Hayate Hayabusa”,

— 3 —
"Tachiakane", "Tachiibuki" and the fallow were 36.5, 34.7, 23.9, 1.9 and 0.2, respectively.

In the succeeding sweet potato cropping, initial densities of the preceding "Tachiibuki" and fallow treatments were significantly lower than the other treatments except for "Tachiakane" followed by a fosthiazate application. Final densities for all treatments were increased by the cropping of sweet potato. No significant difference in final density was observed among the treatments, although the density of the preceding "Tachiibuki" cropping treatment and preceding "Tachiakane"-nematicide treatment were relatively low. Conversely, the final density of the preceding fallow treatment was considerably high in spite of the lowest initial density.

Egg production of root-knot nematodes on oat

Table 1. The numbers of eggmasses° of four Meloidogyne incognita populations in pot treatments testing the multiplication of the nematode on oat varieties.

<table>
<thead>
<tr>
<th>Oat variety</th>
<th>Nematode population (Pathogenic race)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Nishigoshi (SP1)</td>
</tr>
<tr>
<td>Haeibuki</td>
<td>107.8 a</td>
</tr>
<tr>
<td>Hyuuga kuro</td>
<td>100.6 ab</td>
</tr>
<tr>
<td>West</td>
<td>82.0 abc</td>
</tr>
<tr>
<td>Super hayate hayabusa</td>
<td>78.8 abc</td>
</tr>
<tr>
<td>COL/NIAS/2001/KAGOSHIMA/11, 30002463</td>
<td>71.4 abc</td>
</tr>
<tr>
<td>COL/NIAS/2001/KAGOSHIMA/11B, 30009831</td>
<td>64.0 abc</td>
</tr>
<tr>
<td>Huyuga kairyo kuro</td>
<td>58.6 bc</td>
</tr>
<tr>
<td>Hay oats</td>
<td>37.4 c</td>
</tr>
<tr>
<td>Saia</td>
<td>31.2 cd</td>
</tr>
<tr>
<td>Tachiibuki</td>
<td>4.4 d</td>
</tr>
</tbody>
</table>

1 Mean number of eggmasses produced on oat root systems inoculated with 500 J2 per pot (n = 3 or 5). Means in a column followed by the same lower case letter are not significantly different at 5% level according to Tukey-Kramer test with square root transformed data.

2 Tested oat varieties were Avena sativa except for "Hay oats" and "Saia" (A. strigosa).

Table 2. Population densities of root-knot nematodes J2° in field plot treatments testing the effect of the preceding summer-sown early forage oat varieties on the succeeding sweet potato cropping.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Summer-sown cultivation of oat in 2005</th>
<th>Sweet potato cropping in 2006</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Initial (Sep. 8th)</td>
<td>Final (Dec. 15th)</td>
</tr>
<tr>
<td>Haeibuki</td>
<td>12.2</td>
<td>445.3 a</td>
</tr>
<tr>
<td>Super hayate hayabusa</td>
<td>12.2</td>
<td>423.7 a</td>
</tr>
<tr>
<td>Tachiakane</td>
<td>15.0</td>
<td>358.2 a</td>
</tr>
<tr>
<td>Tachiibuki</td>
<td>7.4</td>
<td>14.3 b</td>
</tr>
<tr>
<td>Fallow</td>
<td>8.2</td>
<td>1.3 c</td>
</tr>
</tbody>
</table>

1 Mean numbers of J2 extracted from 20 g fresh soil samples by the Baermann funnel technique (n = 3).

Means in a column followed by the same lower case letter are not significantly different at 5% level according to Tukey-Kramer test with log (X + 0.5)-transformed data.

2 Fosthiazate (1.5% a.i.) was applied to soil at 20 kg / 10 a before sweet potato planting.
roots in the field plot test:

The eggmass density on "Tachiibuki" was significantly the lowest (Table 3). Further, the egg density on "Tachiibuki" was also the lowest, although not always significant.

Yield and quality of storage root of sweet potato in the field plot test:

The total and the marketable yields for the preceding "Tachiibuki" cropping treatment were significantly higher than those for "Haeibuki" or "Super Hayate Hyabusa", and almost identical to "Tachiakane" followed by a fothiazate application (Table 4). Marketable yield for the preceding fallow treatment was significantly lower than that for the preceding "Tachiibuki" treatment, in spite of the lower initial nematode density. The total yield and marketable yield of the preceding fallow treatment did not significantly differ from those of the preceding "Haeibuki" which had the highest nematode density prior to sweet potato planting.

**DISCUSSION**

The present study showed the small reproduction of *M. incognita* on the oat variety "Tachiibuki" (Table 1). This was also confirmed by the low J2 population density of *Meloidogyne* spp. after summer-sown cultivation of "Tachiibuki" in the field plot test (Table 2). Prevention of yield loss on successively grown sweet potato compared to the other varieties and the fallow treatments suggested that fall cropping of "Tachiibuki" could be used to suppress root-knot nematode damage (Table 4).

Host status for *M. incognita* varies among oat varieties (Opperman et al., 1988; Pedersen and Rodriguez-Kabana, 1987). Ibrahim et al. (1993) showed no reproduction of *M. incognita* on oat cultivar "Coker 716" and no reproduction of *M. arenaria* on "Florida 502". In our

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Table 3. Egg production of root-knot nematodes on the roots of early forage oat varieties at the end of summer-sown cultivation in field plot treatments.

<table>
<thead>
<tr>
<th>Oat variety</th>
<th>Eggmass1</th>
<th>Egg2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Haeibuki</td>
<td>41.3 b</td>
<td>712.0 b</td>
</tr>
<tr>
<td>Super Hayate Hyabusa</td>
<td>45.3 a</td>
<td>640.9 a</td>
</tr>
<tr>
<td>Tachiakane</td>
<td>29.4 a</td>
<td>457.9 ab</td>
</tr>
<tr>
<td>Tachiibuki</td>
<td>1.8 b</td>
<td>257.0 b</td>
</tr>
</tbody>
</table>

1 Means are the eggmass numbers / gram of fresh oat root (n = 3).
2 Means are the egg numbers / eggmass (n = 3).

Means in a column followed by the same lower case letter are not significantly different at 5% level according to Tukey-Kramer test with log (X + 0.5)-transformed data.

Table 4. Yield and quality of storage roots of a sweet potato cultivar "Kokei 14" in field plot treatments testing the effect of the preceding summer-sown early forage oat varieties on suppressing root-knot nematodes damage.

<table>
<thead>
<tr>
<th>Oat variety in preceding cropping</th>
<th>Fothiazate application before sweet potato planting</th>
<th>Total yield1</th>
<th>Marketable yield1,2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Haeibuki</td>
<td>-</td>
<td>242.3 b</td>
<td>5.6 b</td>
</tr>
<tr>
<td>Super Hayate Hayabusa</td>
<td>-</td>
<td>212.8 b</td>
<td>13.9 b</td>
</tr>
<tr>
<td>Tachiakane</td>
<td>+</td>
<td>524.7 a</td>
<td>414.5 a</td>
</tr>
<tr>
<td>Tachiibuki</td>
<td>-</td>
<td>490.0 a</td>
<td>382.5 a</td>
</tr>
<tr>
<td>Fallow</td>
<td>-</td>
<td>362.9 ab</td>
<td>18.4 b</td>
</tr>
</tbody>
</table>

1 Means are the weights in grams / plant of storage roots that exceeded 50 g (n = 3).
2 Means in a column followed by the same lower case letter are not significantly different at 5% level according to Tukey-Kramer test.
2 Root weight with no or slight nematode damage.
study, the small reproduction of $M$. incognita populations tested on “Tachiibuki” was clearly confirmed in both the greenhouse and the field plot tests. Small reproduction of $M$. arenaria on “Tachiibuki” was also observed (unpublished data).

It would appear that the warm climatic conditions in Kyushu during the fall cropping season are suited for nematode infestation. Average soil temperatures at 15 cm depth monitored in September, October and November in 2005 were 26.3, 22.0 and 14.9°C, respectively. Roberts et al. (1981) showed the penetration of $M$. incognita J2 to wheat roots occurred at soil temperatures above 18°C. Thus it seemed that the penetration to oat roots could occur until middle November when soil temperature was below 18°C all day long. Considering the total effective temperature for $M$. incognita growth (Gotoh, 1973), this summer cultivation of oat sown in early September was enough for the progress of one generation. The cumulative temperature during the summer-sown cultivation period from late August (earliest sowing) and late September (latest sowing), to December was predicted to allow progression of two and one generation, respectively. Because a small but apparent reproduction of the nematode on “Tachiibuki” was observed (Tables 1 and 3), it seemed that nematode reproduction was influenced by the sowing date.

The mechanism responsible for poor nematode reproduction on “Tachiibuki” has not yet been clarified. There was no difference in the number of J2 that penetrated into the roots between the suppressive “Tachiibuki” and the non-suppressive “Haeibuki” (unpublished data). The lower nematode reproduction on “Tachiibuki” compared to the other varieties seems to result from a failure of J2 developing into matured females. However, the reduced reproduction of $M$. incognita on “Tachiibuki” should differ in mechanism from the total absence of reproduction on known nematode-resistant plants such as siratro ($Macroptilium atropurpureum$) (Sano et al., 1983).

Combination of forcing sweet potato cropping for table use and summer-sown “Tachiibuki” cultivation can be used as a practical cropping system without overlapping of each cropping season. Cosmetic damage of storage roots caused by the nematode, which severely lowers the market value in Japan, was suppressed by the preceding “Tachiibuki” cropping as well as by nematicide application (Table 4). However, the reason for the poor marketable yield with the preceding fallow treatment, despite the lowest initial density of the nematode (Table 2) was unclear.

There was no difference in nematode numbers and crop yield in a crop rotation study in which a fallow treatment was compared with winter cropping of an oat variety similar to “Tachiibuki” (Minton and Bondari, 1994). The cause of the high final nematode numbers and low yield of the fallow treatment requires further study.

It is important to clarify the optimum conditions, such as sowing date, in order to enhance the nematode suppressive effect of summer-sown “Tachiibuki” cultivation.

**LITERATURE CITED**


*arenaria* and *M. incognita*. Supplement to Journal of Nematology 25, 858-862.


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