APPLE ROOT-KNOT NEMATODE, *MELOIDOGYNE MALI*, ITS TAXONOMY, ECOLOGY, DAMAGE, AND CONTROL

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TAXONOMY

The apple root-knot nematode, *Meloidogyne mali,* was described by Itoh, Oshima, and Ichinohe in 1969 (2). In their diagnostic study, this species was figured as "the perineal pattern is characterized by the oval-shape, low arch, smooth and finely spaced striae, a distinct fold over the anus, large phasmids below the surface, phasmids situated wider apart than the length of vulval slit, circular striae on the tail tip region, and the distinct lateral lines." There are some other characteristic morphology in the males as well as the second stage larvae

Table 1. Comparisons of *Meloidogyne mali* n. sp. with *M. arenaria* in the length of vulval slit and distance between phasmids of female perineal pattern (after Itoh, *et al.*, 1969)

Species	Length of vulval slit (μ)	Distance between phasmids (μ)	Reporter
M. arenaria	—	28—31	Chitwood (1949)
"	31.6 ± 3.2	30.4 ± 4.8	Itoh *et al.* (1969)*
M. mali n.sp.	18 (12—24)	22 (17—29)	

*The 16 female specimens of Dropkin's pure population reared on tomato.

M. mali is said to be resemble to *M. arenaria* in the general form of the female perineal pattern, but differs in the length of vulval slit and the distance between phasmids (Table 1).

This nematode, as far as reported, cannot reproduce on rice *(Oryza sativa),* wheat *(Triticum aestivum),* potato *(Solanum tuberosum),* tomato *(Lycopersicon esculentum),* pepper *(Capsicum annuum),* sweet potato *(Ipomoea batatas),* strawberry *(Fragaria chiloensis),* yam *(Dioscorea batatas),* garden balsam *(Impatiens balsamina),* plantain *(Plantago asiatica).*

ECOLOGY

M. mali is distributed in apple orchards in the northern part of Honshu (mainland) and Hokkaido (northernmost part of Japan). The nematode reproduces on the roots of apple trees *(Malus pumila* var. *dulcissima)* and causes damage to the plant growth.

To know the sequence of the nematode development, an inoculation experiment was made with young apple seedlings planted in 2-m^2 micro-plots. All of the seedlings used in the series of experiments were grafted on the stock of *Malus micromalus.*

Abundant second stage larvae were found in the roots 4 weeks after inoculation (Fig. 1). The third and fourth stage larvae were seen 4 weeks later, and their percentages to the total number of the nematodes were always high through the period from 10 to 22 weeks (final examination) after inoculation; while that of the second stage larvae remarkably decreased after 16th week. Both male and female adults appeared first, 12 weeks after inoculation and increased till 20th week. In this week, the egg masses were observed and

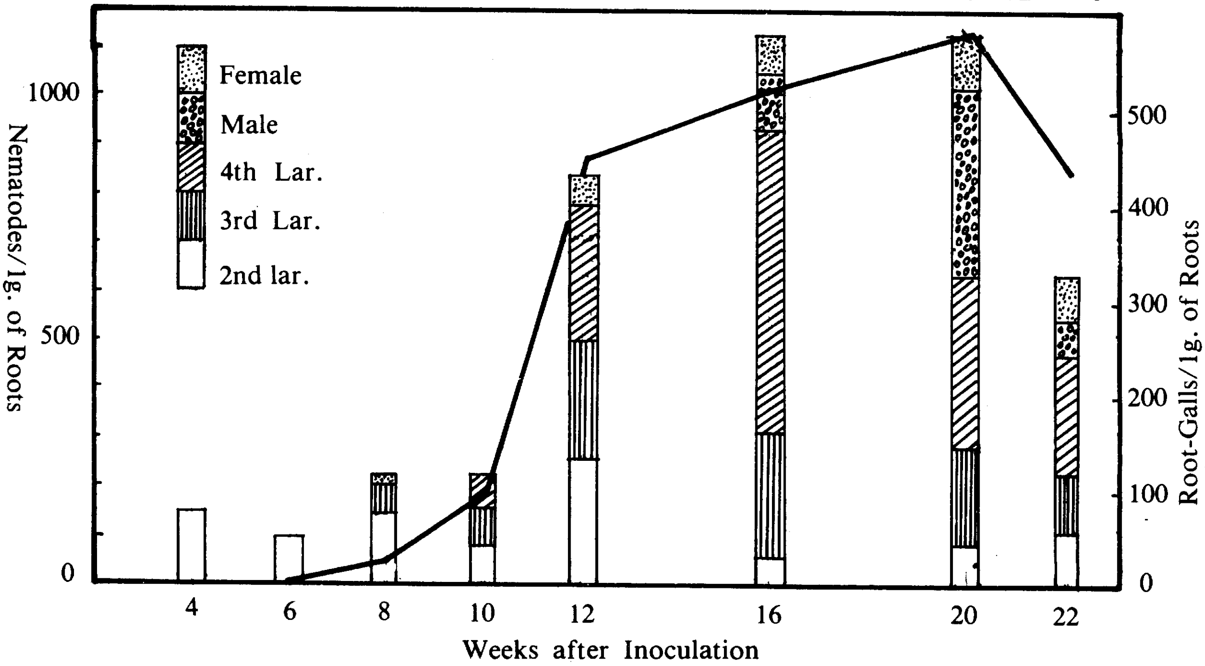

Fig. 1. Development of *M. mali* on apple roots.

some second stage larvae were seen in them 2 weeks later.

Slight swellings were first observed on the roots 6 weeks after inoculation and the number of the root-galls induced by the nematodes became high after 10th week.

It was found that this species of nematodes needed 18-22 weeks for completing one full generation and that only one generation took place in a year.

Vertical and horizontal distribution of the second stage larvae were studied in a commercial apple orchard in late July and the beginning of September, respectively. Most of the nematodes were found to be distributed in the soil profiles from the surface to 25 cm in depth (Fig. 2).

A few nematodes were found down to 50 cm. in depth (deepest sample). As to the horizontal distribution, the nematodes were abundant near the tree (20-40 cm.) and in the area a little away from the tree (120-160 cm.) (Fig. 3). These patterns of nematode distribution were thought to be closely related with the development and distribution of the roots of apple trees in the soil.

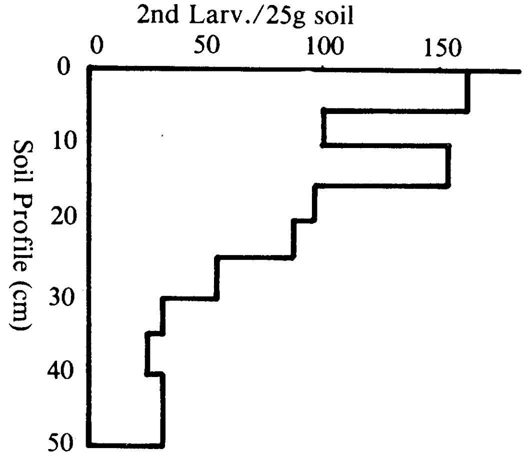

Fig. 2. Vertical distribution of the second stage larvae of *M. mali* in the soil profile of a commercial apple orchard.

DAMAGE:

To understand the damage in apple trees caused by the apple root-knot nematodes, another inoculation experiment was done with seedlings and a survey was made for aged trees.

Seedlings were planted in late April in several 2-m^2 micro-plots where chopped apple roots heavily infected with the nematodes were buried. Nematode infection and plant growth were examined at about 2-week intervals.

The inoculated seedlings were found to have been heavily infected with the nematodes at the final examination in the autumn (Fig. 4). The growth of new shoots was better in the non-inoculated plants than in the inoculated ones both in number (Fig. 5) and length (Fig. 6). The 2-week interval measurements revealed that the elongation of the new shoots was delayed in the inoculated plants (Fig. 7). This was due to the fact that the secondary shoots developed in these plants. The percentage of the number and length of the secondary shoots was remarkably higher in the inoculated plants than in the non-inoculated ones (fig. 8).

Since the appearance of the secondary shoots is a sign of abnormal growth under inadequate conditions, water stress for example, the obvious increase of them in the nematode-infected apple seedlings is interpreted as a kind of symptom and damage induced by the nematodes.

Number of leaves was also smaller in the nematode-infected trees than in the normal ones (Fig. 9)

In total, the growth reduction in young apple trees caused by the apple root-knot nematodes was estimated for various items. The growth of the nematode-infected seedlings was reduced by 15-43 % according to the items measured in comparison with the non-infected ones. The reduction ratios were higher in CV. Asahi than in CV. Kogyoku.

Nematode damage in aged apple trees (36-

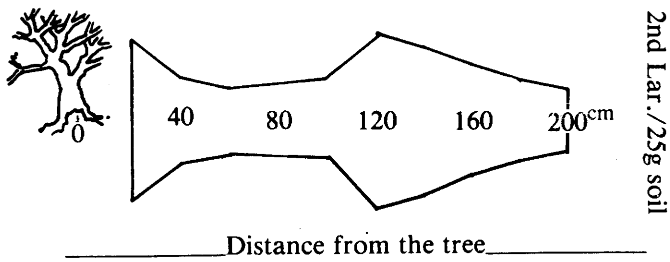

Fig. 3. Horizontal distribution of the second stage larvae of *M. mali* in a commercial apple orchard.

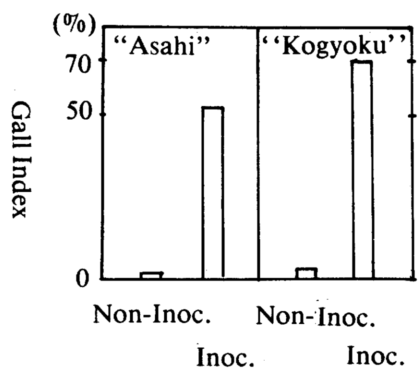

Fig. 4. Gall formation on apple roots inoculated with *M. mali*.

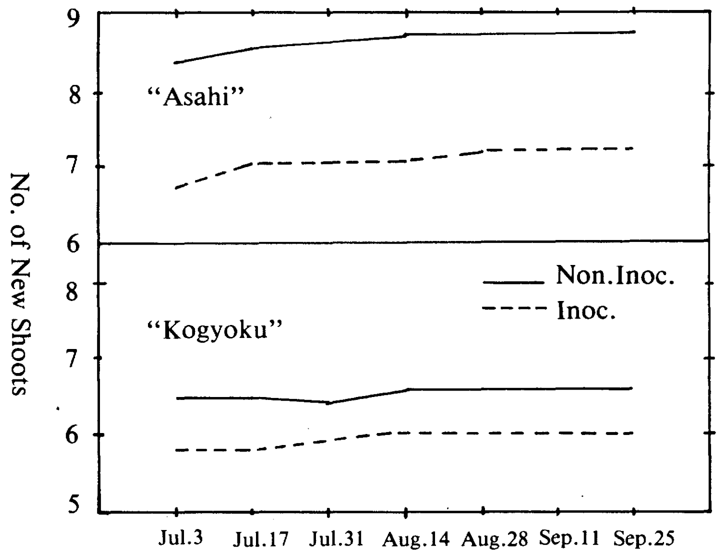

Fig. 5. Difference in number of new shoots between *M. mali*-inoculated and non-inoculated apple seedlings.

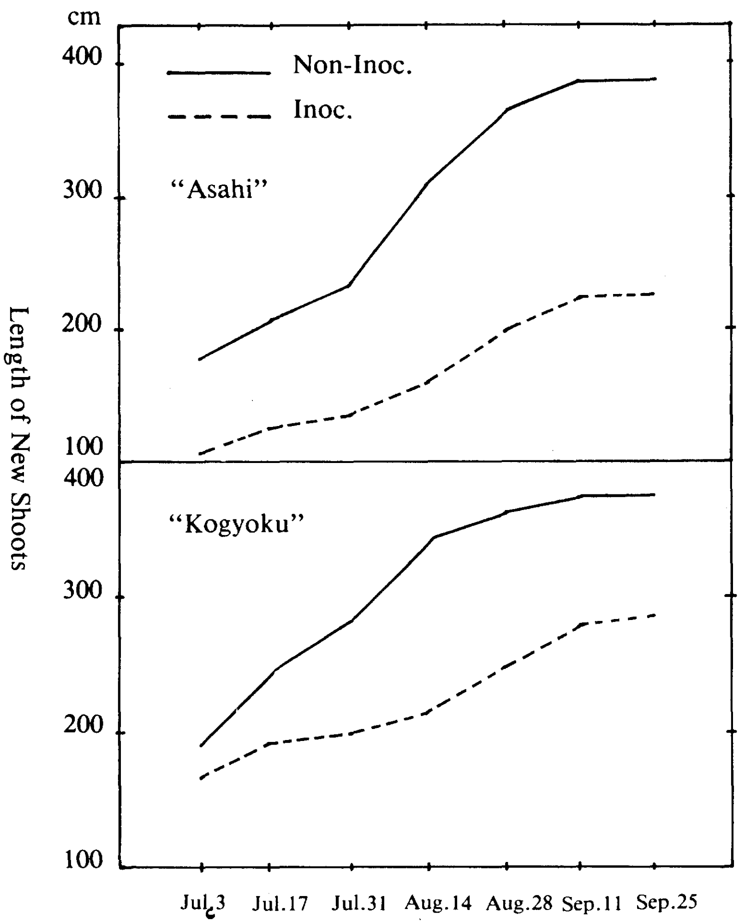

Fig. 6. Difference in length of new shoots between *M. mali*-inoculated and non-inoculated apple seedlings.

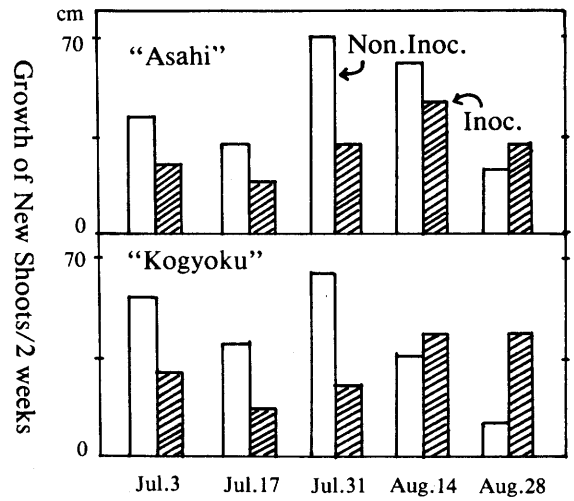

Fig. 7. Difference in growth of new shoots between *M. mali*-inoculated and non-inoculated apple seedlings in every 2 weeks.

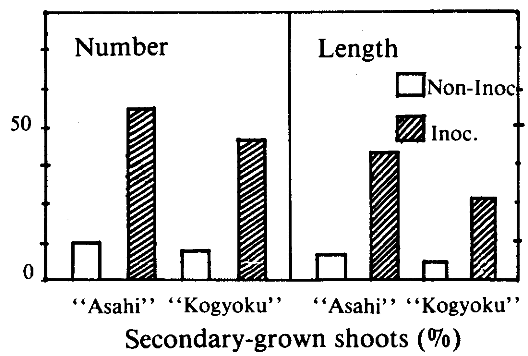

Fig. 8. Comparison of the length of secondary-grown new shoots in *M. mali*-inoculated and non-inoculated apple seedlings.

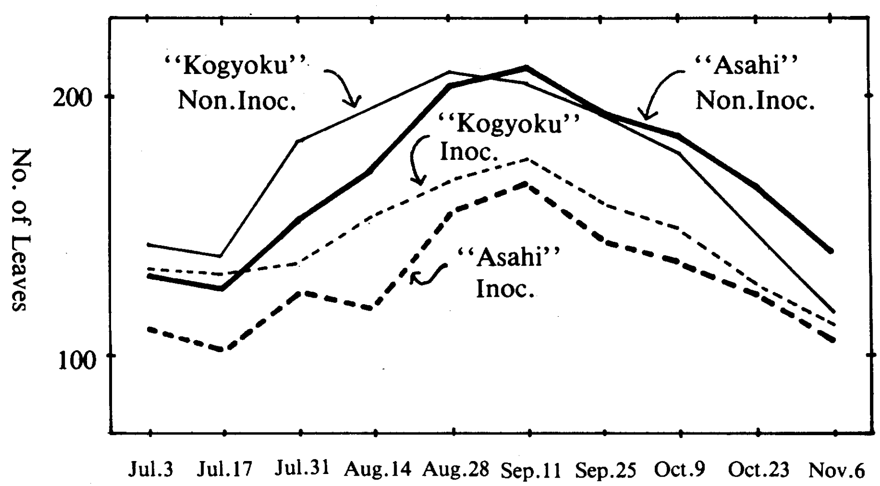

Fig. 9. Number of leaves of *M. mali*-inoculated and non-inoculated apple seedlings.

Table 2. *M. mali* infection and the growth of aged apple trees in commercial orchards.

Cultivar	Gall index	No. of trees	2nd lar/ 25g. soil	Length of new shoots	Wt. of leaves	Fruit yield Good	Medium	Poor
	0	1	0	39.3 cm.	15.5g.	0	0	1
Kogyoku	1-2	7	11	41.5	15.9	3	4	0
	3-4	13	82	36.5	15.0	2	0	11
	0	13	1	32.3	23.2	2	8	3
Asahi	1-2	10	14	32.1	19.9	2	7	1
	3-4	28	92	28.0	18.5	4	3	21

Table 3. Effect of DBCP in controlling *M. mali* on apple seedlings.

Treatment	No. of galls/ 10 cm. roots	No. of leaves	No. of new shoots	Total length of new shoots
DBCP (80 %, Em.)ai 10 g/m^2	0.1	127	4.7	188.4c.
Check	21.8	116	4.1	166.1

50-year-old) was indistinct in general (Table 2). Although the degrees of nematode infection were clearly different among 72 apple trees examined, only insignificant differences were noted in the growth. Fruit yield was, however, generally poor in those graded as heavily infected groups.

Control

To control the nematodes, DBCP was applied to young as well as aged apple trees.

In case of the seedlings, the treatment with DBCP (80 %, Em.) at 10 g a.i./m^2 was found to be effective to reduce nematode infection and the plant growth was better by 10-15 % than the non-treated ones (Table 3.) The effect of chemical treatment was not clear in the aged trees. This might be due to the short period of the experiments and observations.

Hence, it was tentatively concluded that the best way of controlling the apple root-knot nematodes was to 1) plant nematode-free seedlings in nematode-free soil, or 2) treat the soil, if infested, with DBCP.

Literature Cited

1. CHITWOOD, B.G. 1949. A revision of the genus *Meloidogyne* Goeldi, 1887. Proc. Helm. Soc. Wash. 16:37-118.
2. ITOH, Y., Y. OHSHIMA, and M. ICHINOHE. 1969. A root-knot nematode, *Meloidogyne mali* n.sp. on apple-tree from Japan (Tylenchida: Heteroderidae). Appl. Ent. Zool. 4:194-202.

DISCUSSION

Sasser: Do you have any idea for studying *M. mali* further under IMP?

Inagaki: We are trying to reproduce the nematode in a green-house culture. We will send the egg-masses to the Center of IMP as soon as possible.

The variety has no significance in reproducing the nematodes, because the seedlings are all grafted on the stock of *Malus micromalus*. So, it is practical to use seedlings of this wild species for multiplying them.

Choi: Don't you find infection of apple roots by aphids?

Inagaki: I think we do have it as well as that with fungi. As far as in our experimental and survey works, we think the damage in the growth of apple trees was caused by the infection with the nematodes, since we examined the presence of the nematodes in the roots.