Distribution and Ecology of Nematode-Trapping Fungi in Japan

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Type of nematode-destroying fungi can be classified for convenience into predatory and endoparasitic. The predators such as trap organ forming fungi as natural enemy of plant parasitic nematodes are well known in many countries,[27] although there are only few reports in Japan. Even in these countries, however, knowledge of their behaviour in fields seems to be limited.

The author attempted to evaluate the role played by nematode-trapping fungi in controlling plant-parasitic nematodes in fields, by investigating species identification, geographical distribution, and biological characteristics in pure culture as well as in fields of the nematode-trapping fungi belonging to Hyphomycetes in Japan.

Detected species of nematode-trapping fungi

Nematode-trapping fungi belonging to Hyphomycetes were isolated from many fields of the following crops located throughout Japan; potato, tomato, soybean, peanut, dasheen, Japanese radish, upland rice, decan grass, peach, and citrus, and from coniferous and broad leaved tree forests by using the soil disk technique, plant debris technique, baiting technique with flax stem, and incubated on acidified corn meal agar containing nematodes, *Aphelenchus avenae* or *Panagrellus redivivus*.

Taxonomic study of these fungi revealed 31 species of which 17 species were new to Japan (Table 1).

Among these species, *Arthrobotrys oligospora, Monacrosporium cytosporum, M. eudermatum, A. dactyloides* and *M. ellipsosporum* appeared dominant. As to the type of trapping organs, the fungi with three dimensional adhesive net were detected at the highest frequency, followed by adhesive stalked knob forming fungi, and constricting ring forming fungi.

Distribution of the trapping fungi in field soils

Vertical and horizontal distributions in peanut fields at Yachimata (Chiba Prefecture) were examined by the flax stem baiting technique.

1) Horizontal distribution

The trapping fungi were detected in June and September from a peanut field of 201.6 m^2 divided into 24 blocks. The most dominant species were three dimensional adhesive net forming fungi (*A. oligospora, A. conoides* and *M. eudermatum*) while constricting ring forming fungi (*A. dactyloides*) and adhesive knob forming fungi (*M. ellipsosporum*) were rare. There was no difference in the distributions between June and September (Fig. 1).

2) Vertical distribution

Vertical distribution of the trapping fungi was examined up to a depth of 30 cm, and the distribution pattern as expressed by detected ratios was different among 3 different sections of the field; Sasabiki, Ozeki and Sumino (Fig. 2).

3) Distribution of the trapping fungi in forest soils

The trapping fungi were detected by the

Table 1. Detected nematode-trapping fungi

Species	Trap organ
Arthrobotrys anchonia Drechsler (1954)	C. R.
A. brochopaga (Drechsler) Schenck, Kendrick and Pramer (1977)	C. R.
A. candida (Nees ex Pers) Schenck, Kendrick and Pramer (1977)	N. C. R., S. A. K.
A. cladodes var. *macroides* Drechsler (1944)	Th. N.
A. clavispora (Cooke) Schenck, Kendrick and Pramer (1977)	Th. N.
A. conoides Drechsler (1937)	Th. N.
A. dactyloides Drechsler (1937)	C. R.
A. doliformis Soprunov (1958)	Th. N.
A. haptotyla (Dreschsler) Schenck, Kendrick and Pramer (1977)	S. A. K.
A. musiformis Drechsler (1937)	Th. N.
A. oligospora (Fresenius) Drechsler (1937)	Th. N.
A. pauca McCulloch (1977)	S. A. K.
A. polycephala (Drechsler) Rifai (1968)	Th. N.
A. superba Corda (1939; Drechsler, 1937)	Th. N.
A. thaumasia (Drechsler) Schenck, Kendrick and Pramer (1977)	Th. N.
A. vermicola (Cooke and Satchuth.) Rifai (1968)	Th. N.
Dactylella asthenopaga Drechsler (1937)	S. A. K.
D. leptospora Drechsler (1937)	N. C. R.
Monacrosporium aphrobrochum (Drechsler) Subramanian (1963)	C. R.
M. bembicodes (Drechsler) Subramanian (1963)	C. R.
M. cinopagum (Drechsler) Subramanian (1963)	T. N.
M. cytosporum Cooke and Dickinson (1965)	Th. N.
M. doedycoides (Drechsler) Subramanian (1963)	C. R.
M. drechsleri (Tarjan) Cooke and Dickinson (1965)	S. A. K.
M. ellipsosporum (Groove) Cooke and Dickinson (1965)	S. A. K.
M. eudermatum (Drechsler) Subramanian (1963)	Th. N.
M. gephyropagum (Drechsler) Subramanian (1963)	T. N.
M. mammillatum (Dixon) Cooke and Dickinson (1965)	S. A. K.
M. mutabilis Cooke (1969)	S. A. K.
M. reticulatum (Peach) Cooke and Dickinson (1965)	Th. N.
M. salinum Cooke and Dickinson (1965)	Th. N.

C. R.; Constricting ring, N. C. R.; Nonconstricting ring, T. N.; Two dimensional adhesive net, Th.N.; Three dimensional adhesive net, S. A. K.; Stalked adhesive knob.

plant debris technique at Mt. Unzen (Nagasaki Prefecture), Mt. Keicho (Tochigi Prefecture), Okunikko district (Tochigi Prefecture) and Towada district around Lake Towada (Aomori Prefecture). Three dimensional adhesive net forming species (*Arthrobotrys* spp., *Monacrosporium* spp.) and stalked adhesive knob forming species (*M. ellipsosporum*) were widely detected from the forest soils. However, stalked adhesive knob forming species of *A. haptotyla* was detected only at Mt. Unzen. Two dimensional adhesive net forming species (*M. cinopagum, M. gephyropagum*) were detected at Mt. Keicho and Towada district, and constricting ring forming species, *A. dactyloides* and *A. brochopaga*, were detected at Mt. Unzen, Towada district and Okunikko district, and *M. bembicodes* was detected at Mt. Unzen and Mt. Keicho (Table 2).

Detection frequency and species composition of nematode-trapping fungi as influenced by planted crops and cultural methods

1) Upland field

Trapping fungi were detected by the plant debris technique from fields of successive cropping of dasheen, sweet potato, upland rice or peanut at the Central Agricultural Experi-

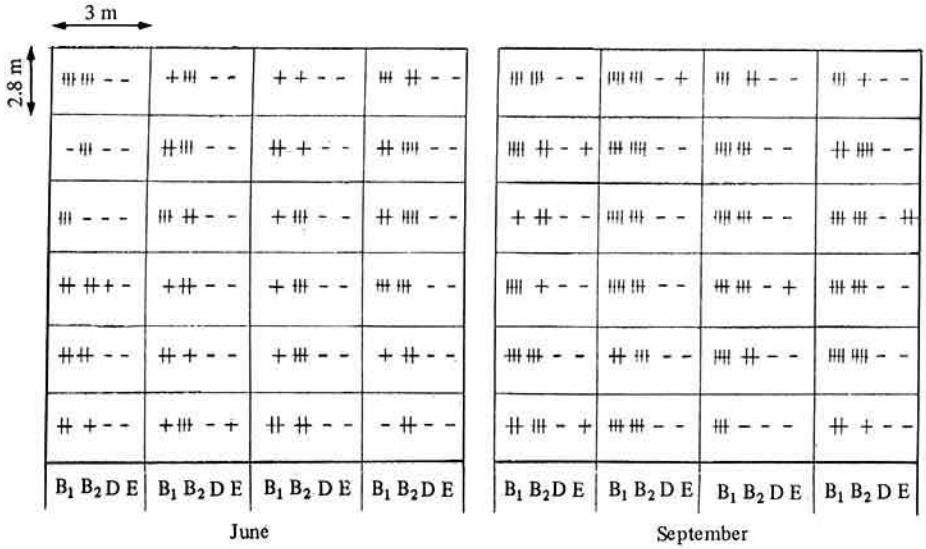

Fig. 1. Horizontal distribution of the trapping fungi in successive peanut field

Dominant species

B_1 : *A. oligospora*, *A. conoides*, B_2 : *M. eudermatum*, D : *A. dactyloides*, E : *M. ellipsosporum*

Detected frequency (%) − : 0, + : 1~5, ++ : 6~10, +++ : 11~20, ++++ : >20

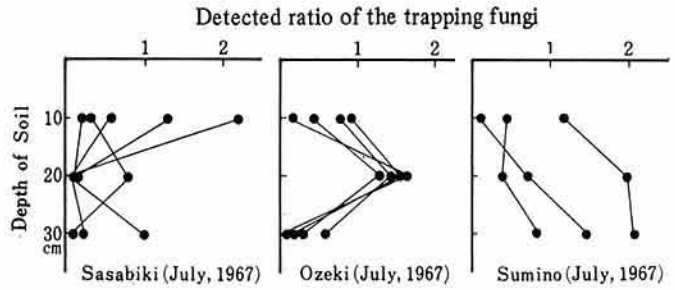

Fig. 2. Distribution of nematode-trapping fungi at different depth of soil in three fields.

ment Station (Kitamoto, Saitama Prefecture), and from fields of rotation crops; potato, corn, wheat, soybean, rape and Japanese millet at Fujisaka Branch, Aomori Agricultural Experiment Station (Aomori Prefecture).

Detection frequency and species composition of the trapping fungi did not show appreciable differences among different crops each successively grown at Kitamoto, except that the detection frequency was higher in potato and corn fields, where compost was applied, than in other fields. In the rotation fields at Fujisaka, the fields where these crops were grown in the preceding year with compost application showed higher detecting rates of trapping fungi than other fields (Table 3, Table 4).

2) Orchards

The trapping fungi were detected by the plant debris technique from 81 peach orchards in 9 prefectures, and 109 citrus orchards in 13 prefectures in May or June, and September.

Some species of trapping fungi were de-

Table 2. Distribution of the nematode-trapping fungi in forest soils

District	No. of place	B_1	B_2	B_3	D_1	D_2	D_3	E_1	E_3
Mt. Unzen	5	−	+	−	++	+	+++	+++	+
Mt. Keicho	20	−	++	+	−	−	++	+++	−
Towada dist.	14	−	+	++	+	+	−	++	−
Okunikko dist.	14	+++	−	−	+	−	−	+++	−

Detection ratio − : 0, ± : 1-30%, ++ : 30-70%, +++ : 70-100%

B_1: *Arthrobotrys* spp. Three dimensional adhesive net
B_2: *Monacrosporium* spp. Three dimensional adhesive net
B_3: *M. cinopagum*, *M. gephyropagum* Two dimensional adhesive net
D_1: *A. dactyloides* Constricting ring
D_2: *A. brochopaga* Constricting ring
D_3: *M. bembicodes* Constricting ring
E_1: *M. ellipsosporum* Stalked adhesive knob
E_3: *A. haptotyla* Stalked adhesive knob

Table 3. Detection ratio of the trapping fungi at Kitamoto

Crop	Trapping fungi					Total
	B_1	B_2	D	E_1	E_3	
Dasheen	2.5	0.6	1.9	1.1	0.3	6.4 %
Sweet potato	1.4	1.4	0.6	3.3	0	6.7
Upland rice	0.6	0.6	0.3	5.6	0	7.1
Peanut	3.1	1.4	0.3	3.0	0.3	8.1

Signs of the trapping fungi are same as Table 2.

tected in a limited number of orchards, while *A. oligospora*, *A. dactyloides* and *M. ellipsosporum* were found in a large number of orcahrds. *M. cinopagum* was detected only from citrus orchards (Table 5). Frequency of detecting fungi was higher in sod culture or grass mulching than in clean culture of peach orchards (Table 6), and in citrus orchards it was observed that adhesive knob forming species were more frequently detected in soils of low pH than in other soils, and more constricting ring forming species were found in soils of neutral pH than in other soils.

Activities of the trapping fungi on agar medium

Growth of hyphae of the trapping fungi on the Czapeck Dox medium containing each of the various saccharides such as sucrose, glucose, starch, maltose, inositol, pectin, carboxy methyl cellurose (CMC) and lignin was examined at 25°C.

The hyphae of constricting ring forming fungi (*A. dactyloides*, *A. brochopaga*) grew well on sucrose, starch CMC, and pectin, while adhesive knob forming fungus (*M. ellipsosporum*) grew well on sucrose and pectin, and adhesive net forming fungi grew well on sucrose and CMC. All of the fungi tested indicated very poor growth on lignin.

Optimum temperature for hyphal growth of *A. conoides*, *A. dactyloides* and *M. ellipsosporum* was 27°C, although the optimum temperature for nematode-trapping activity of the fungi was different among species, i.e., 27°C for *A. dactyloides*, and 20° to 25°C for *A. conoides* and *M. ellipsosporum*.

Influence of pH of culture medium on growth of hyphae and trap organ formation of the trapping fungi, and on multiplication of fungivorous nematode (*Aphelenchus avenae*) on the culture medium was examined on corn meal agar medium with pH adjusted with citrate buffer or phosphate buffer.

Optimum pH of culture medium for growth of hyphae differed between citrate buffer and phosphate buffer, and this was true for trap organ formation. Better hyphal growth and trap organ formation were observed at neutral pH of the medium except *M. ellipsosporum* which grew well at low pH. The nematode multiplication was suppressed most effectively

Table 4. Number of trapping fungi and nematodes detected from rotation fields

Crop	Previous crop	Soil pH	Nematode			Trapping fungi			Total
			F	P	Pi	B	D	E	
Potato	R	6.0	488	299	0	18	0	0	18
	W	6.0	1047	618	0	4	15	0	19
	W	5.7	501	93	2	9	8	0	17
	C	5.7	876	178	0	17	1	1	19
	C	5.5	376	57	0	25	4	24	63
Wheat	P	5.5	498	100	0	3	25	0	28
	P	6.1	1127	885	2	12	2	0	14
	R	6.3	1017	638	35	3	0	0	3
	P	5.6	1232	895	0	9	0	0	9
	R	5.7	1880	181	0	12	0	0	12
Corn	W	5.8	675	357	0	15	1	0	16
	W	6.9	1085	683	0	22	0	0	22
Rape	P	5.4	287	83	0	12	0	0	12
	P	5.3	827	279	0	5	0	10	15
J. millet	W	5.7	818	203	208	2	0	0	2
	J	5.8	698	785	0	10	0	0	10

B : adhesive net, D : constricting ring, E : adhesive knob, F : Free living nematodes, P : *Pratylenchus* sp., Pi : Pin nematode, P : potato, C : corn, W : wheat, R : rape, J : Japanese millet.

Table 5. Number of orchards from which trapping fungi were detected

	Month sampl.	No. garden	B_1	B_2	B_3	B_4	D_1	D_2	D_3	E_1	E_2	E_3	E_5
Citrus	May	108	47	52	14	0	67	4	3	31	8	6	2
	September	109	77	3	10	11	60	0	4	55	48	23	1
Peach	June	75	31	1	0	1	32	7	0	30	5	6	0
	September	81	40	3	0	3	35	2	4	45	11	11	47

B_1: *A. oligospora**
B_2: *M. eudermatum**
B_3: *M. cinopagum*
B_4: *A. musiformis*
D_1: *A. dactyloides*
D_2: *A. brochopaga*
D_3: *M. doedycoides*
E_1: *M. ellipsosporum**
E_3: *A. haptotyla*
E_2, E_5: Unidentified
*: Dominant species

Table 6. Detection frequencies of trapping fungi by cultivation method of peach orchards

Trapping fungi	B_1	B_2	B_3	B_4	D_1	D_2	D_3	E_1	E_2	E_3	E_5
Clean culture	34.5	7.7	0	0	30.8	0	00	69.2	26.9	15.4	15.4
Grass mulching	48.1	11.1	0	0	59.3	3.7	11.1	59.3	25.9	70.3	14.8
Sod culture	52.4	9.5	0	0	33.3	0	0	52.4	19.0	57.1	19.0

Signs of the trapping fungi are same as Table 5.

Table 7. Effect of medium pH on hyphal growth, conidia and trap organ formation, and nematode multiplication

Trapping fungi		Citric buffer								Phosphate buffer		
		3.0	3.6	4.2	4.8	5.4	6.0	6.4	7.0	7.0	7.5	8.0
A. oligospora	T	−	−	±	−	−	+	+	+	++	++	++
(17 B_1)	H	4.0	8.3	27.5	13.5	5.8	5.0	6.0	44.0	>90	>90	>90
	C	−	−	−	−	−	−	−	+	++	++	+
	N	+	+	+	+	+	±	±	−	−	−	−
A. dolyformis	T	−	−	−	+	+	+	+	+	++	++	+
(347 B_4)	H	4.0	4.0	8.0	7.5	4.0	4.0	4.0	14.8	25.5	17.5	19.0
	C	−	−	−	+	++	+	++	++	+++	+++	++
	N	±	±	+	±	−	−	−	−	−	−	−
A. musiformis	T	−	±	−	+	−	+	+	++	+	++	++
(80 D_4)	H	4.0	9.0	20.8	25.8	23.3	8.0	18.9	29.5	28.0	25.0	23.0
	C	−	−	+++	++	++	++	++	+++	+++	+++	+++
	N	+	+	+	+	+	+	±	−	+	+	+
A. musiformis	T	−	−	−	−	−	−	−	+	±	±	±
(S 50 D_4)	H	4.0	11.0	20.0	23.6	27.3	28.3	19.0	30.8	38.0	33.8	31.3
	C	+	+	+	++	+	+	+	+	++	++	++
	N	−	+	+	+	+	+	+	+	+	+	+
M. eudermatum	T	−	−	−	±	−	−	±	+	±	+	+
(O 6 B_2)	H	9.5	18.5	40.0	11.5	13.8	9.3	12.3	38.8	90	90	90
	C	++	++	++	−	−	−	+	++	+++	+	+
	N	+	+	+	+	+	+	+	+	+	±	±
M. eudermatum	T	−	−	+	−	−	±	±	±	±	±	±
(104 B_2)	H	9.0	16.5	26.0	14.8	10.0	14.3	23.0	15.3	90	90	90
	C	−	−	−	−	−	−	−	+	+	+	−
	N	+	+	+	+	+	+	+	+	+	+	+
A. dactyloides	T	−	−	+	++	++	++	++	++	++	++	++
(418 D_1)	H	4.0	6.0	21.0	9.5	6.0	4.0	4.0	6.0	19.8	10.3	8.0
	C	−	−	+	+	−	−	−	+	+++	++	−
	N	±	±	+	−	−	−	±	−	−	−	−
A. dactyloides	T	−	+	+	+	−	+	+	+	+	+	+
(485 D_2)	H	4.0	10.0	12.8	6.0	4.0	4.9	9.0	7.0	12.0	11.0	9.0
	C	−	−	−	−	−	+	+	+	+	+	+
	N	+	+	−	+	−	−	−	−	−	−	−
N. ellipsosporum	T	++	+++	++	++	++	+	+	−	+	+	−
(CaE_1)	H	19.3	45.0	37.3	25.0	10.8	10.0	9.0	4.0	4.0	4.0	4.0
	C	+++	+++	+++	−	−	−	−	−	+	−	−
	N	−	−	−	−	±	±	±	±	+	+	+

T : Frequency of trap organ formation, H : Diameter of colony (mm), C : Frequency of conidia formation, N : Nematode multiplication.

−: not recognized, +: recognized, ++ : frequently recognized

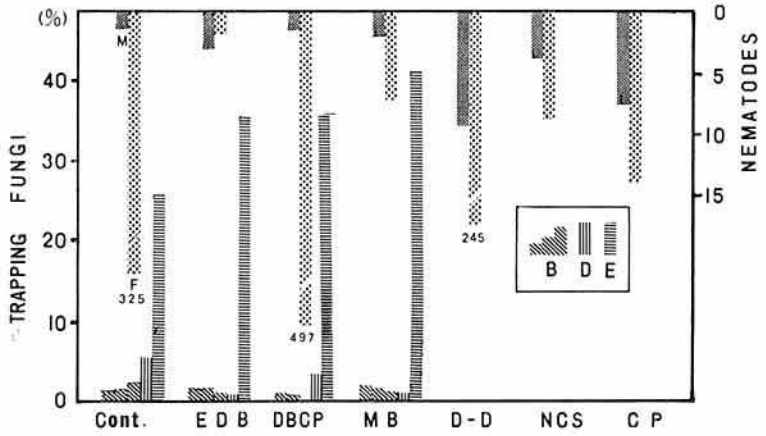

Fig. 3. Effects of the trapping fungi on the population of nematode.

M : *M. incognita*, F : Free living nematodes, Trapping fungi :Percentage of detection with soil disk technique, B : Three dimension networks, D : Constricting ring, E : Adhesive knob, and morphologically unmodified organ.

by *M. ellipsosporum* at a wide range of pH (Table 7).

Germinated conida of *A. dactyloides*, *A. brochopaga* and *M. ellipsosporum* formed trap organ readily even under nutrient-free conditions if nematodes were present, but *M. eudermatum*, *A. doliformis*, *A. superba* and *A. cladodes* var. *macroides* showed a decreased ability of trap organ formation under the similar conditions.

Activity of the trapping fungi in soils

1) In fumigated soil

Activity of the trapping fungi was evaluated on the basis of the decrease of the population level (determined by the Baermann funnel technique) of *Meloidogyne incognita* which was reinoculated to the soil previously fumigated with the following nematicides; Dibromochloropropane (DBCP), dibromoethane (EDB), methylbromide (MB), dichloropropane-dichloropropene (D-D), chloropicrin (CP) and ammonium-N-methylisothiocarbamate (NCS).

Fungicidal effect of fumigation on the trapping fungi was low with DBCP, EDB and MB but was high with D-D, CP and NCS. Population level of *M. incognita* 14 days after reinoculation, which had made 30 days after fumigation was higher in D-D, NCS and CP plots than other fumigation plots. This result shows that the trapping fungi were more active in the DBCP, EDB and MB plots than in other plots (Fig. 3).

2) Field survey

Activity of the trapping fungi was evaluated by the relationship between population density of the trapping fungi and that of *M. hapla* at different locations of 23 peanut fields of volcanic ash soil at Yachimata (Chiba Prefecture) where the peanut had been cultivated successively for more than three years. The trapping fungi were detected by the flax stem baiting technique, i.e., the trapping fungi were detected on acidified corn meal agar after flax stems of 17 cm long were buried in soil of peanut intrarow space for two weeks. The nematode population density was estimated by root-knot index of cucumber seeded in the same place, and the same periods of flax stem baiting in June and August, and by peanut

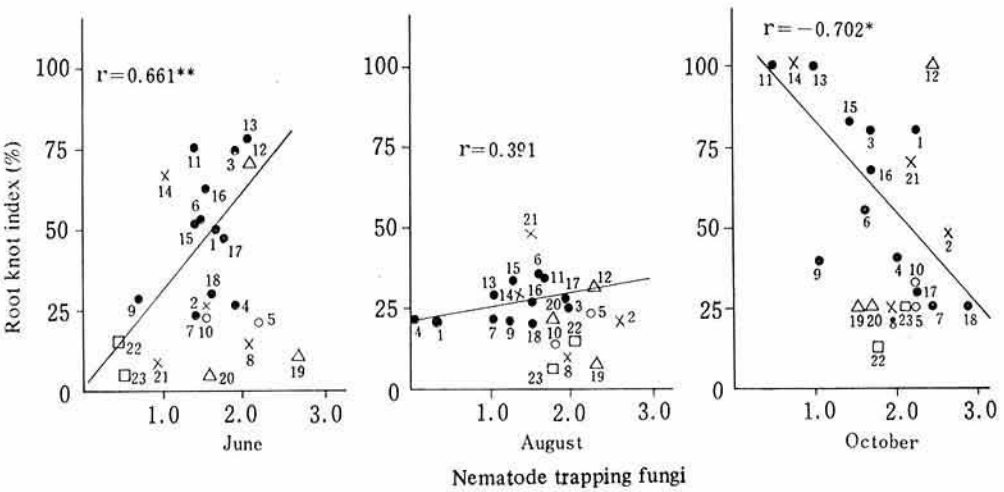

Fig. 4. Relationships between nematode trapping fungi and root-knot indices at peanut fields in the three seasons

Numbers in the figures indicate the field number. Characters of fields are indicated by signs as follows, △ : Deeply plowed, □ : Treated with EDB, × : Low land, ○ : Low pH of soil, ● : Ordinal.
Nematode trapping fungi in the abscissas were indicated in the isolation ratios from the flax stems buried in soils for 2 weeks.

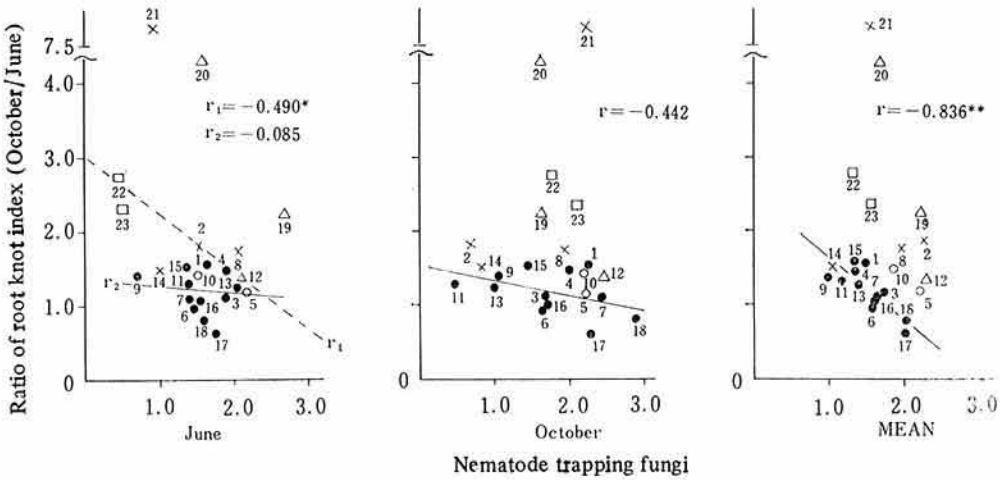

Fig. 5. Relationship between nematode trapping fungi and ratios of root-knot indices in peanut fields

Signs and numbers in the figures are same to those in Fig. 4.
The ratios of root-knot indices were calculated by dividing the root-knot index in later date with that in earlier date.

root-knot index in October.

A positive correlation with a high coefficient between population level of the trapping fungi and the root-knot indices was observed in June in 14 fields with the exception of deeply plowed fields, low land fields, and fields with low pH of soil, but a negative correlation with a high coefficient was observed in October in 12 fields except EDB treated fields which were included in the 14 fields of the June test. Furthermore, a negative correlation with a high coefficient was observed between the mean of population levels of the trapping fungi in June, August, and October and the ratio of root-knot indices of October to those of June in 12 fields (Fig. 4, Fig. 5).

These results prove that the role of trapping fungi becomes clear when a whole year fluctuation of nematodes and the trapping fungi is taken into account, although the correlation between both organisms is positive or negative depending upon the seasons.

Effects of soil additives on trapping fungi

Effects of application of plant residue, manure, dung, compost and soil amendment on population density of the trapping fungi and nematode population level were examined by pot or field experiments in Chiba Prefecture using soils infested with *M. incognita* or *M. hapla*, and in Kanagawa Prefecture using soils infested with *Pratylenchus penetrans*.

1) Pot tests

Five grams of rice straw and 2 g of ammonium nitrate were added to 200 g of *M. hapla*-infested soil in glass vessel, and the mixture was incubated at 25°C. Trapping fungi were detected by the soil disk technique, and nematodes were isolated by the Baermann funnel technique at one week intervals.

Application of rice straw effectively increased the activity of the trapping fungi, and the further addition of ammonium nitrate further increased the activity (Fig. 6).

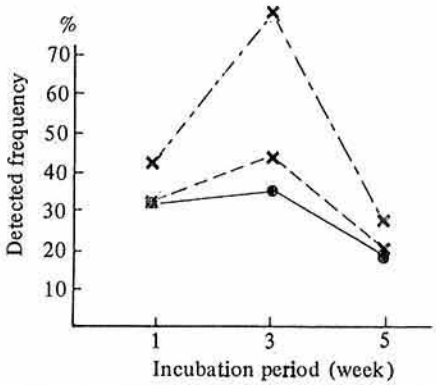

Fig. 6. Effects of rice straw and added ammonium nitrate on activity of the trapping fungi
× - - - × Rice straw
× ····· × Rice straw + NH_4NO_3
● —— ● Untreated control

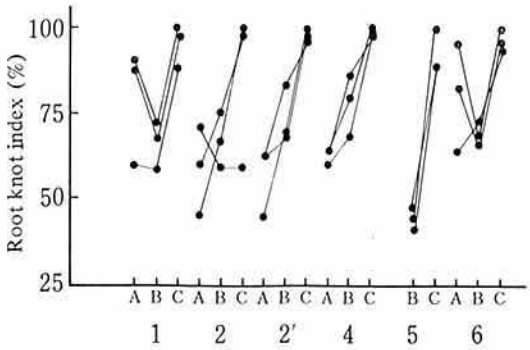

Fig. 7. Fluctuations in root-knot indices of peanut in October at Sasabiki field which was treated with various amendments during from 1966 to 1968
A : 1966, B : 1967, C : 1968.
1 : Iron sludge, 2 : Rice straw manure, 2′ : Rice straw manure (double dose of 2), 4 : Peanut plant manure, 5 : Sawdust manure, 6 : Untreated control.

2) Field tests

Iron sludge, rice straw manure, peanut plant manure, or sawdust manure was applied successively for 2 or 3 years in peanut fields of volcanic ash soil at three sections, Sasabiki, Sumino, Ozeki at Yachimata (Chiba Prefecture). Population levels of trapping fungi and *M. hapla* (as expressed by root-knot indices)

were examined.

The application of these substances was ineffective in raising the population level of trapping fungi, and differences of root-knot indices of *M. hapla* were not recognized (Fig. 7). However, a positive correlation with a high coefficient was observed between population levels of the trapping fungi, and the root-knot indices in June, and it changed to a negative correlation in October, as in the case of the above-mentioned peanut field experiment.

Similar experiments conducted at Chiba (Chiba Prefecture) where dung of cattle and pig, manure made from rice straw, and fermented chaff were applied to *M. incognita*-infested fields successively cropped to pumpkin, and at Miura (Kanagawa Prefecture) where cabbage shoots, rice straw manure, or various soil amendments were applied to *P. penetrans*-infested fields cropped to water melon, Japanese radish and cabbage in rotation.

In these experiments, no correlation was found between population levels of the trapping fungi and population levels of nematode or their increase.

Effects of trapping fungus inoculation

The inoculum of the trapping fungi cultured with barley grains of 100 g was inoculated to a volcanic ash soil infested with *M. incognita*. In pot tests *A. oligospora*, *A. pauca*, *A. haptotyla*, *A. brochopaga*, *M. ellipsosporum* and *M. cinopagum* were inoculated to two kg of potted soil on which pumpkin was growing, and in field tests *A. haptotyla*, *A. dactyloides*, *M. cinopagum* and *M. ellipsosporum* were inoculated to the rooting zone of transplanted egg plants.

In the pot tests using the soil infested with *M. incognita*, *A. haptotyla* decreased the nematode population most effectively among six fungus species tested (Table 8).

In the field tests *M. cinopagum* most effectively decreased the nematode population among four trapping fungus species tested but the detection ratio of inoculated trapping fungus species was very low, and the total detection ratio of the trapping fungi in the inoculated plot was similar to that of the non-inoculated plot after inoculation for 4 months (Table 9).

Table 8. Effects of the trapping fungi inoculation on nematode (*M. incognita*) control

	A. brochopaga	*M. cinopagum*	*A. haptotyla*	*A. pauca*	*A. oligospora*	*M. ellipsosporum*	*A. haptotyla*	Check
Root-knot index	3.7	3.3	3.0	3.0	3.0	3.0	1.0	4.0
Growth of pumpkin(m)	2.37	1.90	2.03	2.63	2.87	2.53	3.27	2.50

Table 9. Detection frequency of the trapping fungi four months after inoculation in soil

Inoculated fungi	B_1	B_2	B_3	D	E_1	E_3	Total / Sample
M. ellipsosporum (E_1)	5	11	0	5	<u>60</u>	0	81 / 120
A. haptotyla (E_3)	1	7	0	7	51	<u>5</u>	71 / 120
A. dactyloides (D)	20	14	0	<u>8</u>	28	0	61 / 120
M. cinopagum (B_3)	17	9	<u>1</u>	3	31	0	70 / 120
Check	5	15	3	4	42	1	70 / 120

B : Adhesive net, B_1 : *Arthrobotrys* sp., B_2 : *Monacrosporium* sp., B_3 : *M. cinopagum*
D : Constricting ring, E_1 : *M. ellipsosporum*, E_3 : *A. haptotyla*
Underlines in figure indicate trap organ of inoculated trapping fungi.

Conclusions

Among nematode-destroying fungi, nematode-trapping fungi are well known and many reports have appeared. Studies in several areas of the world show that the majority of species of nematode-trapping fungi are cosmopolitan.

An excellent key to the identification of the nematode-destroying fungi was published by Cooke and Godfrey,[8] and thereafter original descriptions of most of the reported species were subjected to taxonomic reappraisals.[6,7,8,25,26]

Surveys for nematode-trapping fungi in Japan revealed the similar flora as in other areas.[1,19,26,27]

Optimum temperature for hyphal growth of nematode-trapping fungi was lower in soil than on agar medium.[21] Generally, optimum temperature for trapping organ formation and nematode-trapping activity was lower than that for hyphal growth.[12] Optimum pH for growth of hyphae was different with different fungus species.[26]

Nematode-trapping fungi which grow faster were considered to have poor nematode-trapping activity, while those with poor hyphal growth produced trapping organs directly from germinated haphae in absence of nutrients, and nematode-trapping activity was different with fungus isolates.

Sensitivity to mycostasis of nematode-trapping fungi varied from species to species,[9,17] and also varied with soil conditions.

Species of nematode-trapping fungi was different by soil depth,[20] but most of them appear to occur in the top 10–30 cm.[22] An appearance of positive correlationship between population levels of nematode-trapping fungi and those of root-knot nematodes in peanut fields in June was similar to the correlationship between the fungi and free living nematode in green houses.[14]

Biological control of plant parasitic nematodes was carried out by adding organic amendments to soils in Hawaii by Linford,[15,16] and the similar reports were admirably summarized by Duddington.[10,11] Thereafter, effects of organic additives on nematode-trapping fungi activity have been reported.[3,4,5,13,18,23] Contrary to expectation, negative results were obtained from field experiments.

Application of cultured *Arthrobotrys* sp. was expected to control root-knot nematode to a low population level in the nematode-infested field in France on commercial base,[2] and *M. ellipsosporum* applied around roots of transplanted tobacco showed a good result.[24] Application of *A. haptotyla* inhibited the multiplication of root-knot nematode to some extent in pot experiments, but its effect was very low in a field application test.

From these results, it is expected that the use of nematode-trapping fungi for controlling nematodes is not so effective as the use of nematicides, so that the fungi may be used in combination with nematicide or crop rotation.

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(Received for publication, March 16, 1984)