Studies on ecology and control of the potato cyst nematode *Globodera rostochiensis* (Wollenweber, 1923) Behrens, 1975

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Summary

The potato cyst nematode has been considered one of the most serious pests of potatoes throughout the temperate regions of the world, because of its difficulty to control.

In most countries free from this nematode, severe hygiene by legislation was enforsed to prevent or delay the introduction of this pest.

This nematode was found for the first time in one of potato fields at Toyokawa, Makkari, Hokkaido in 1972. The present investigation was conducted to clarify the ecology of the nematode and develop control measures. Most experiments were conducted primarily under field conditions during from 1973 to 1982.

1. Occurrence of the potato cyst nematode in Japan

Some specimens of potato variety "Benimaru" were brought to the Hokkaido Central Agricultural Experment Station for identification of the pathogen which had caused poor growth in the middle of July, 1972.

These plant were those which a grower noticed in his field occurring during the past few years at Toyokawa, Makkari, a southern central part of Hokkaido.

By the morphological examinations of larvae, adults and cysts, the causal agent was identified as potato cyst nematode, *Heterodera rostochiensis* Wollenweber (Fig. 1, 2).

Population level of the nematode in this field was found very high, and poor growth of potato plants was characteristic (Table 1).

Later in 1977, the same nematode was found in Kiyosato, an eastern part of Hokkaido, and, in 1980 at Toyoura, a vicinity of Makkari.

The acreage of the nematode infested fields reached 4,272 ha in total in 1985 all of which were restricted to Hokkaido (Table 3).

2. The plant symptoms of potatoes caused by the potato cyst nematode

The symptoms of the above-ground part of a susceptible potato variety "Benimaru" in the nematode highly infested field at Makkari in 1973 are as follows. The first noticiable signs of potato plants was slight wilting early in July. Wilting of an overall plant and discoloration of lower leaves were also observed middle in July which is bloom season of "Benimamu" potatoes. Late in July, leaves begun withered and falled (Plate 1, A). Plants showing severe symptoms were deteriorated and dead, while those with slight symptoms left several leaves on the upper part of the stem loosing and hanging down, so that they showed so-called "Feather duster" symptom all over the field middle to late in August (Plate 1, B), and all of the potatoes died more than one month

earlier than those of uninfested field.

3. Analysis of damage of potato crops in microplot and in field test

The negative correlation coefficients between nematode population level (number of eggs per g dry soil) and potato yields were evident showing Seinhorst's curve based on Nicolson's competition curve which generally fitted than that of regression equations.

The reduction rate in potato yields based on Seinhorst's equation were 8% at "Benimaru" and 6% at "Tunika" by microplot tests, and 4% and 2% by field test, respectively (Fig. 4, 5).

The nematode population levels in relation to the rate of reduction in potato yields were classified as low level for less than 10 eggs per g soil, median for a range of 11-100 eggs, and high level for more than 100 eggs per g soil.

The multiplication rate of nematodes was higher when preplant population level was lower under field conditions of susceptible potatoes (Fig. 6).

4. Seasonal fluctuation in the nematode population under field conditions

1) Comparisons among susceptible varieties

To examine seasonal occurrence of the potato cyst nematode in potato varieties with different maturities, "Irish Cobbler" (early variety), "Benimaru" (median late variety), and "Hokkai-aka" (extreme late variety) were used. Patterns of occurrence were very similar among the varieties tested, while the number of nematodes infested were different.

Invation of roots by the nematode occurred early to middle in June. The peak of total number of nematodes was early in July (Fig. 7). Yellow females were maximum in number early to middle in July when they were readily visible with naked eyes. Since the number of cysts adhering to the roots decreased in August and they mostly turned brown, it was recommended that nematode inspection by potato roots should be made by the middle of July (Fig. 9).

2) Comparison among resistant varieties.

Introduced potato varieties, "Ehud" and "Tunika", were used. The nematode infestation occurred even in these resistant potatoes, but almost all of invaded nematodes failed to develop up to adult females. The planiting of resistant varieties can be expected as trap-crop of potato cyst nematodes, because a 60-90% reduction in preplant nematode population level was resulted (Fig. 11, 15).

3) Non-host crops.

Nematode population in soil was reduced when nonhost crops were cultivated, and reduction rate averaged 30% per year (Fig. 16). Accordingly, it was confirmed that a crop ratation including nonhosts is one of the useful means for reduction in nematode population.

4) Fluctuation of nematode population at different depths of soil.

When susceptible potato variety was cultivated, nematode population within a layer between 0 to 10cm deep remarkably increased, resulting into as much as 930% of that at planting time, which was followed by the layer of 11-20cm deep with 283% increase at a site within a row. When resistant potato variety was cultivated, nematode population decreased up to less than 30% of that at planting time in a layer between 0 to 30cm deep within the row, and 70% at site between rows

(Fig. 18).

Effect of Vydate (1%) treatment of 30kg/10a in combination with susceptible potato variety resulted into high reduction in a population within a layer 0 to 10cm deep, but less effective in the layer deeper than 11cm (Fig. 19).

5. The length of life cycle under field conditions

The length of life cycle of nematodes was examined from July to August in fields. The potatoes were planted in non-infested field in advance in May and transplanted in nematode infested field from early June to late July. The length of life cycle was estimated by the first finding of a brown cyst since the transplanted date. The length was about 40 days (Table 9).

6. Tolerance of nematode to extreame temperatures

The tolerance of eggs to low temperature was found extreamely high, and the eggs in cysts were alive under the conditions at −20°C——160days in dry soil (Table 12). The eggs were killed at 80°C——10sec., 75°C——20sec., 70°C——30sec. in hot water treatment (Table 13).

7. Age of potato secreting the most effective root diffusate for hatching

Examination of hatching rate of eggs indicated that the most effective diffusate was secured from early flower bud-appearing stage to early flowering stage of potatoes (Table 14).

8. Parasitism of tomatoes by potato cyst nematode

All of 29 tomato varieties tested were susceptible to potato cyst nematodes (Fig. 21).

9. Measures for controlling the potato cyst nematode

1) Effect of crop rotation

The changes in potato cyst nematode population under different crop rotations (2, 3, 5, 7, 9 year) including continuous cropping were examined in a high nematode infested field (552 eggs per g dry soil).

The nematode population increased after susceptible potato "Benimaru", and decreased after resistant potato "Tunika".

Averaged rate of decrease in population after nonhost crops was 32%. The rate of decrease in population differed depending to the preciding crops, that is, 59.4% after susceptible variety, 61. 0% after resistant variety, and 25.9% after nonhosts (Table 16).

The rate of decrease in nematode population was not observed among the nonhost crops tested (Table 17).

The nematode population after continuous cropping with susceptible potato "Benimaru" resulted in high between from 200 to 700 eggs, but decreased to 0.5% of initial population after 6 year continuons cropping of resistant potato "Tunika" (Fig. 24).

In the test of a 9 year crop rotation, the nematode population decreased up to 22 eggs after 8 year cultivation of nohost crops, but increased the population to the initial level by the cultivation of susceptible potato in the ninth year after preciding 8 year nonhost cropping (Fig. 24).

The yield of popatoes restored according to the length of crop rotation. Continuous cropping of susceptible potatoes "Benimaru" yielded 40%, and resistant potatoes "Tunika" 51% of that of non-infested field. A 4 year crop rotation was considered to be one of the practical methods, if this was combined with nematicide application (Table 18, 19).

2) Screening of potato varieties resistant or torelant to potato cyst nematode, and their utilization as control measures.

Resistance of wild potato species was examined with the roots infested by yellow females. Resistance was observed by 1 strain of *Solanum andigena*, 3 strains of *S. famatinae*, 5 strains of *S. vernei*, 1 strain of *S. oplocence* and *S. multidissectum* (Table 20).

The infestation degree of females and cysts and yield of susceptible varieties or strains were examined. Selected varieties with somewhat lower cyst index are "Kameraz" (Cyst index 25), "Koniku No. 10", "Iwate No. 4", "Kamiya-imo No. 1", "Kintoki-imo", "Shikokuzairai No. 2", "Voran", and "Bihoro" (26-50), and high yield was obtained by "Kintoki-imo", "Koniku No. 4", and "Iwate No. 4".

Varieties which have yield despite of a high cyst index were "Norin No. 1", "Eniwa", and so forth.

Resistant 6 varieties and 10 strains were examined in the nematode highly infested field (Table 21).

Number of 2nd stage larvae in the maximum invation period of root appeared no much differences from those of the susceptible ones, but adult females or cysts were extreamely few. The nematode population in soil after harvest decreased 60-80% that of planting time (Table 22).

The yields of resistant varieties or strains were 65.3-86.8% that of uninfested field (Table 23). "Tunika" was only one resistant variety which appaered in practical use nematode infested fields.

3) Effect of nematicides on potato cyst nematode, and their usage as control measures.

Several nematicides were tested in heavily infested volcanic ash soils.

Fumigants : In spring application, both D-D and EDB controlled nematodes in proportion to the dosage, but the sprout and growth of potato plants were delayed by the phytotoxicity, and the yields decreased with the increase in dosage. It was concluded that spring application is not practical in Hokkaido (Table 24). The autumn application (from September to October) of 60 liter / 10a of D-D or 30 liter / 10a of Di-trapex were found effective without any phytotoxicity, and this treatment adapted to Hokkaido (Table 25, 26). Since the nematode population was very low in those plots where nonhost crops had been cultivated and, however, nematode population was sometimes higher in potato plots than those of untreatrd plots, the fumigants should be used in comibnation with nonhost crops. Twice applications at one half dose were more effective than a single application at regular dose (Table 28).

The nematode population at harvest time in the plots where nonhost crops had been cultivated was decreased to 20-40% of that at planing time (Table 27).

Non-fumigated granular nematicides : Overall treatment of 30kg of Vydate (1%), 30-40kg of Diazinon (5%), 15-20kg/10a of Mocap (5%), and ridge treatment of 15kg of Vydate, 10kg/10a of Mocap at planting time of potato effectively controlled nematodes. The number of viable eggs in the soil after harvest was smaller than that of untreated plot. The growth and yield of susceptible potato "Benimaru" was greatly improved (Table 29, 31).

Effect of autumn application was not observed (Table 30)

4) Reduction in nematode population by trap crops, and their utilization.

Field tests were conducted to find out the effect of nematode trapping plants on the reduction in the nematode population, and their utilization was considered.

A high invation of roots by the nematode as well as very poor cyst formation was observed on the following plants; *Solanum tuberosum* (resistant variety "Tunika"), *Solanum nodiflorum*, *Lycopersicon peruvianum* B6001 (P. I. 126926), and *Solanum nigrum*. Planting of these plants resulted in a high reduction in the nematode population level in soil (Table 35).

S. nigrum highly reduced the nematode population by seeding of 2g/m^2 in May and June, or intercropping in sweet corn in May, but seeding in wheat harvested field at the end of August failed to reduce the nematode population.

Resistant potato variety "Tunika" was found effective when planted into sweet corn field in May or June, and similarly even at the end of August immediately after harvest of wheat.

No nematicidal effect of *Tagetes patula* and *T. erecta* was observed.

5) Effect of artificial hatching agent "Picrolonic acid" on the reduction of nematode population in soil.

Picrolonic acid was spread on the surface and incorporated into the soil about 20cm deep. The application of 15g/m^2 during May to July stimulated hatching and emergence of larvae from cysts, and resulted the nematode population (eggs in soil) less than 5% of that before treatment (Fig. 29).

6) Effect of ultrahigh frequency electromagnetic energy (2,450 $\pm$ 20MHz) on the reduction in the nematode population in soil.

UHF energy was irradiated on the surface of moistend or dry cysts, in soils of different moisture contents, wet (36.4%) and dry (10.1%).

Irradiation raised temperatures of soil 5cm deep which was followed by 10cm deep and soil surface.

Immediate after irradiation, soil temperature was 70-95°C in wet soil and 60-85°C in dry soil at 4,000 Joules・cm^2・sec. irradiation, and 75-100°C and 65-95°C at 8,000 Joules, respectively (Fig. 30).

The lethal rate for eggs in wet cysts was higher than that of dry cysts (Fig. 31). All eggs of any combination of cyst and soil were killed at a depth of 15cm at 8,000 Joules irradiation (Table 39).

7) Effect of Cobart 60 irradiation on eggs in cysts.

Cobart 60 irradiation ranged from 5 to 1,280 Krad was examined to wet or dry eggs in cysts.

Hatching rate of eggs was markedly decreased at 320 Krad, and no hatching occurred at 640 Krad under both wet and dry conditions. Generally, the effect of irradiation was high on wet cysts than on dry cysts. In second generation, irradiation was effective above 40 Krad and completely lethal above 640 Krad on dry cysts, and effective above 20 Krad and lethal above 160 Krad on wet cysts (Table 42, Fig. 32).

8) The prevention and nematode transmission by the soil separated from potatoes in

nematode infested fields.

(1) Lethal effect on nematodes by burning nematode infested soil.

All of eggs in cysts in the nematode infested soil were killed by heating soil from 60°C to 80°C by Hexapet, a machine of keroshin burner, piling to a heap and covering by vinyl sheet for 18 hours (Table 43).

(2) Lethal effect on nematodes buried in the heap of compost on the process of mature.

The soil including cysts were placed in the heap of compost, consisting of the soil separated from potatoes and refuse after starch separation, from September to November or December. All eggs were killed mainly by the fermented heat exceeding 50°C (Table 44).

(3) Lethal effect on nematodes under the soil of settling pond of starch manufactory.

The eggs in cysts mostly died when cysts were placed under the soil of settling pond during from Octover to July of the next year (Table 45). The causes of death of eggs were considered to be the reduction in oxygen because of oxygen-reduction potential (Eh 6 value) of 0, and to be the generation of bydrogen sulfide which caused cyst color turned to blach perhaps due to deposition of pigment of iron sulfide (Fig. 33).

(4) The posibility of contamination of potato dregs with cysts on the process of starch production.

To learn possibility of contamination of the dregs with cysts on the process of potato starch, potato tubers of "Norin No. 1" were transported and washed by water on the manufacturing process. Since a very small amount of cysts were remained on the surface of potato tubers, the possibility of contamination was not denied (Table 46).

9) The prevention of transmission of soil separated from sugar beets of nematode infested soil.

(1) The rate of death of eggs buried in the heap of soil separated from sugar beet indicated that almost all eggs died (Table 47).

(2) The rate of death in the soil of settling pond of sugar manufactory.

The eggs in cysts died complately when cysts were placed under the soils of settling pond of sugar manufactory from September to July of the next year. The causes of death were considered to be the reduction in oxygen and generation of hydrogen sulfide, as resulted from starch manufactory (Table 48, Fig. 34).

10. Investigation for the integrated control of potato cyst nematode under field conditions

Based on the above-mentioned results, the most effective methods to keep the nematode population low in the nematode infested fields are the combination of 4 year crop rotation, cultivation of resistant varieties, and application of nematicides of fumigants and non-fumigation grannules (Fig. 35, 36, 37, 38).

The reduction in nematode population was resulted from the combination of fumigants and cultivation of nonhost crops (Table 53).

The cultivation of potatoes both susceptible and resistant should be limited to the field of low population level so that to prevent yield loss of potatoes. Non-fumigation granular nematicide, Vydate and so forth, can be applied to the cultivation of susceptible potatoes to prevent from increase in nematode population (Table 53).

It was resulted that the nematode was maintaind in low level when these combination were succeeded (Fig. 39).

Plate 1. Potato cyst nematode and above-ground symptoms of a susceptible potato "Benimaru".
A : Damaged field in late July (Leaves begun withered and falled).
B : "Feather duster" symptom in late August.
C : Yellow females. D : Cysts.