VÄLISAUTORID

INTEGRATED CONTROL OF POTATO CYST NEMATODE, *GLOBODERA ROSTOCHIENSIS*, IN FINLAND

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The effect of crop rotation on *Globodera rostochiensis* (Wollenweber, 1923) and potato yield were studied in 1981…1991 in southern Finland. Six different cropping systems were tested. In the plots with potato monoculture, the tuber yield decreased from 35 to 4.6 t ha^{-1}. Cropping systems with potato once in 5, 4 or 3 years maintained the yield at the original level. Continuous growing of susceptible potato raised the population density of the nematode from 0.1 to 265 eggs g^{-1} soil in four years. After that the density fluctuated between 25 and 136 eggs g^{-1} soil. The nematicide treatments (oxamyl) did not control nematode multiplication but prevented yield losses. Growing of resistant (H1) potato reduced the nematode population by 80% and a non-host crop (oats) reduced it by 60% on average. The cropping system that can be recommend is potato once in three years with a resistant and susceptible cultivar grown alternately. No nematicide is registered no needed for control of potato cyst nematode in Finland.

Key words: *potato cyst nematode, integrated control, crop rotation, resistance, nematicide.*

Introduction

In Finland the potato cyst nematode (PCN) was first found in Hyvinkää (60 00 N, 24 50 E) in 1946 (Vappula, 1954). At the beginning of the 1980s PCN was common in southern Finland and was regarded as the most harmful nematode pest in the country. So far only *Globodera rostochiensis* has been found. The pathotype Ro1 is dominant but some resistance – (H1) – breaking *G. rostochiensis* populations have been found (Heikkilä, Tiilikkala, 1992). The nematode has been controlled by crop rotation, resistant cultivars or early harvesting; no nematicide is registered in Finland for control of potato cyst nematode. At the time when this experiment was started pressure by chemical companies to get nematicides accepted was actively being applied.

The control of potato cyst nematode is on of the main reasons for crop rotation in potato production throughout Europe (Vos *et al.*, 1989) and many kinds of rotation have been used. Hijink (1972), for example, reported that the rotation of potatoes once in 4 years is an effective system for controlling potato cyst nematode. In other growing conditions, a gap of 6…12 years between potato cropping is required in order to avoid crop damage (Trudgill *et al.*, 1987). Resistant potato cultivars and chemical control are widely used as integrated nematode control on farms specialised in potato production (Phillips, 1989). Combining two or more control strategies is likely to be the basis of future management of plant-parasitic nematodes (Roberts, 1993).

However, cropping systems which have been tested in Central Europe cannot be applied directly in Finland. It has been proved that climatic factors, mainly low temperature accumulation, limit the pest potential of potato cyst nematode in Finland (Tiilkkala, 1991) where the production area of potato extends from the southern coast (60 00 N) to Lapland (69 00 N).

The aim of this study was to get information for planning integrated pest management of potato cyst nematode and for development of sustainable potato cropping systems in Finnish climatic conditions. A special objective was to show that nematicides are not needed because the nematode can be controlled with cultural methods alone.

Material and methods

The crop rotation field study was conducted on a farm situated in southern Finland (60 50 N, 24 15 E). The soil type in the experimental field was coarse sand and the field had been known to be infested by *Globodera rostochiensis* (PCN) for many years before the experiment was started.

The effects of six different cropping systems on potato yield and nematode density were studied from 1981 to 1991. The cropping systems are given in Table 1.

Table 1. Cropping systems of the field study in 1981…1991. S = susceptible potato (Bintje), R=H1 resistant potato (Prevalent), Sn = susceptible potato protected with nematicide (oxamyl), O = oats grown as the intermediate non-host crop.

Cropping	Years										
system	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	1991
1	S	O	O	O	O	S	O	O	O	O	S
2	S	O	O	O	S	O	O	O	S	O	S
3	S	O	O	R	O	O	S	O	O	R	S
4	S	O	R	Sn	O	S	O	R	Sn	Sn	S
5	S	Sn	O	Sn	S	O	Sn	S	O	O	S
6	S	S	S	S	S	S	S	S	S	S	S

Each cropping system comprised five replicate plots (3×8 m) in a strip. The strips were isolated from each other by a 2-m wide grass strip. The plots were ploughed and tilled in spring and fertilised in the years 1981…1987 with pig slurry. A chlorine-free NPK fertiliser (8-11-12) was used at a rate of 800 kg/ha in the years 1988…1991. The nematicide (VYDATE L, oxamyl) was sprayed before planting with a propane-operated knapsack compression sprayer at the rate of 4.8 kg a.i./ha and incorporated into the top 15 cm of the soil with rotavator just before the potatoes were planted. Each potato plot had four rows, 75 cm apart and 8 m long. Potatoes were planted every year between May 20 and May 25 with a semi-automatic or automatic planter spacing of 25 cm within the rows. Weed control was accomplished with metribuzin (0.5 kg a.i./ha) and late blight was controlled with two sprays every year: the first with metalaxyl + mancozeb and the second with maneb. The potatoes were harvested by hand during the second week of September and the tuber yield was weighed from the two middle rows of each plot. The yield of tubers of all sizes is presented as total yield (t/ha) in this paper. From 1984 the tuber yield was sorted into four size groups: smaller then 35 mm, 35…50 mm, 50…75 mm and larger than 75 cm. Tubers smaller than 35 mm were not included in the marketable yield.

The growing of the non-host crop of oats followed standard farming practice for fertilisation and weed control. The oats were harvested by hand from 8 m^2 per plot and threshed with a trial harvester.

For estimation of the nematode population densities a soil sample of 50 cores, each 2.5 cm in diameter and 20 cm deep, was taken from each plot before planting and after harvesting. The samples were air-dried and PCN cysts extracted by a Fenwick can from 2×200 g dry soil per sample. Hand-picked cysts were squashed by an electrically driven perspex rod in a glass tube and the numbers of eggs and juveniles counted under a microscope and presented as eggs per g dry soil. The Pf/Pi (final population density/initial population density) values were calculated using the spring population estimate of a year as Pi and spring population estimation of the following years as Pf. The soil mixing effect of tillage was thus the same on both of the estimates. Cyst contents, eggs per cyst, were calculated from spring samples only.

The growing season effective temperature sums (ETS) were computed for each year above a base temperature of 5° C. The weather data was obtained from the routine measurements made by the Finnish Meteorological Institute at Jokioinen (60 50 N, 23 30 E). The ETS values are presented in Figure 1. The numerical data were analysed with SPSSX and SAS statistics.

Figure 1. Effective temperature sums (ETS) above 5° C at Jokioinen (60 82 N, 23 50 E) in 1981…1991. The horizontal line is the long-term mean (1190 day-degrees) for the period (1960…1990)

Results

Population density of PCN

In 1981 initial population densities of the PCN in each cropping system (n) were 0.4 (1), 0.4 (2), 1.6 (3), 3.4 (4), 3.0 (5), and 0.1 (6) eggs/g soil. population increase of the nematode was controlled effectively in cropping systems 1, 2 and 3. In cropping system 1, the average nematode population density remained at 1 egg/g soil. The minimum density was 0.1 and the maximum 4.6 eggs/g soil (Fig. 2).

Figure 2. Effective of the six cropping systems on the population density (Pi) of PCN. Numbers on the x-axis are for the six cropping systems and population density of PCN is presented as eggs/g soil on the y-axis. The bars (from left to the right) are for the years 1981 to 1991

In cropping system 2 the average nematode population density was 4 eggs/g soil, with a maximum density of 12 eggs/g in spring 1986 after cultivation of the susceptible potato. Cultivation of three non-host crops (in 1986...1988) reduced the density to the minimum level of 0.1 eggs/g (Fig. 2).

Cropping system 3 was the most effective for nematode control. In many of the plots the nematode density dropped below the detectable level after spring 1987. The highest density was recorded in spring 1982 after which the number of eggs declined steadily.

Cropping system 4, 5 and 6 were ineffective at controlling population increase (Fig. 2). In system 4, the average nematode density was 12 eggs/g soil with a peak in the spring of 1991 when 27 eggs/g soil were found after the cultivation of two susceptible potatoes in succession. Both of these potato crops were protected with the nematicide treatment. The minimum density in this system was 0.1 eggs/g, recorded in spring 1989 after cultivation of the resistant potato.

Two peaks of nematode densities were found in cropping system 5; the first (118 eggs/g) in spring 1983 and the second (150 eggs/g) in spring 1986 (Fig. 2). Both of the peaks followed cultivation of the susceptible potato. In the first case, potatoes were grown with the nematicide treatment and in the second without the treatment. The minimum density of 4 eggs/g soil was recorded after the exceptionally cold summer of 1987.

Continuous cropping of the susceptible potato (cropping system 6) increased the population density in the first years of the experiment (1981...1984) from 0.1 to 265 eggs/g soil. After that, the density fluctuated between 25 and 136 egg/g, with an average value over the 11 years of the experiment of 64 eggs/g. The minimum nematode density was found in the spring of 1988, as in many of the other cropping systems, after the coldest growing season of the experiment (Fig. 2).

Over the whole experiment, the multiplication rate of the nematode varied between 0.2 and 33 times per annum (average 11) when susceptible potatoes were grown without the nematicide treatment. With the nematicide, the Pf/Pi value was 15 on average (min. 0.1, max. 47). In the non-host plots the Pf/Pi value was 0.4 on average during the first season after potato cultivation but the value varied considerably (min. 0.1 and max. 1.0). When the resistant potato cultivar was grown the multiplication rate of PCN averaged 0.2 times per annum.

The numbers of eggs per cyst differed significantly between years ($F=7.55$, $P<0.01$). The lowest cyst contents in the whole experiment were found in spring 1988, when the numbers of eggs/cyst were almost at the same level as at the beginning of the experiment in 1981 (Fig. 3). Comparison of the cropping systems with data for the year 1991 showed that system 1 kept the cyst contents at a lower level (6.3 eggs/cyst) than any other system apart from system 3 ($F=28.0$, $LSD=14.2$). In the monoculture cropping of the susceptible potato the average number of eggs/cyst was the highest (60 eggs/cyst) were susceptible potatoes were grown in monoculture (Fig. 4).

Potato yields

In the monoculture of susceptible potato (system 6) the total yield decreased from the original level of 34.5 to 4.6 t/ha. The biggest yield decrease occurred in 1984 when the nematode population density reached its peak value in the monoculture plots. The relationship between initial nematode density and potato yield was clear (Fig. 6), with yield decreasing steadily until the nematode density reached 150 eggs/g soil.

In cropping system 1, 2 and 3, the yields of potatoes remained at the original level (32.3 t/ha). The nematicide treatment used in systems 4 and 5 did not control nematode development but it did prevent yield losses. The mean yield of susceptible potatoes in plots treated with oxamyl was 37.2 t/ha and the highest potato yield of the experiment (63.5 t/ha) was recorded in system 5 in 1984, when the susceptible potato was grown with nematicide treatment. Over the whole experiment the mean yield of the resistant potato was 39.9 t/ha. All the resistant potato crops were preceded by the non-host crop, which obviously lowered the nematode stress on the resistant crops.

Figure 3. Cyst contents (eggs/cyst) for each year of the experiment. The numbers are yearly means of all the cropping system

Figure 4. Effects of the six cropping systems on cyst contents (eggs/cyst). Numbers are the average the average values per system for the eleven years of the experiment

Analysis of the marketable yields in 1991 showed clearly ($F=35.5$, $P<0.001$) that cropping systems with a good crop rotation (systems 1, 2 and 3) gave a higher yield than the systems with a narrow rotation (systems 4 and 5) or monoculture cropping (system 6) of susceptible potato (Fig. 7).

Figure 5. Total potato yields in the experiment as t/ha. Yields of the resistant potato are marked with ® and yields of the susceptible potato grown with the nematicide treatment with (sn). Unmarked bars are for yields of the susceptible potato grown without the nematicide treatment

Figure 6. Relationship between potato yield and initial nematode density (Pi). The data is from the plots which grow susceptible potato as continuously

Figure 7. Effect of the cropping systems on the marketable potato yields in the last year of the experiment (black bars). Yields are presented as mean values for each cropping system (LSD=3.2 t/ha). White bars are for the total yields which also included tubers smaller than 35 mm

Discussion

Under the present climatic conditions in Finland PCN can be controlled without any nematicide treatment. The cropping system that can be most strongly recommended is potato once in three years with a resistant and susceptible cultivar grown alternately. By this practice the population density of *G. rostochiensis* (Ro1, Ro4) can be kept below the economics threshold or even under the level of detection. It should also be good enough to prevent, or at least limit, the selection of new pathotypes as Jones *et al.* (1967) have suggested. In Poland a 10-year study pointed out that good rotation for a susceptible potato cultivar was 1year in 5, and for a resistant cultivar it was about 1 year in 3 to 2 years in 5 (Zawisla *et al.*, 1989).

In continuous cultivation of the susceptible potato the population density of PCN increased, peaked and then fluctuated in a typical way for plant parasitic nematodes (Jones, Parrot, 1969). The maximum average number of eggs per cyst was 52.9, somewhat less than fount in field population in more southerly areas (e.g. Salazar, Ritter, 1992). Heikkilä and Tiilikkala (1992) have also reported that the number of eggs per cyst is often very low in Finland. The Pf/Pi ratio when the resistant potato cultivar was grown was 0.2, showing a reduction of the nematode population by 80 per cent. This result is the same as is generally recorded (Trudgill *et al.*, 1987) in field conditions.

Cultivation of the non-host crop decreased the population density of PCN by 60 per cent on average, but Whitehead (1995) reported that populations of *G. rostochiensis* declined at annual rates of only 12.8…40.5% when spring barley was grown. This difference may be due to the long-day conditions in Finland in that Salazar and Ritter (1993) reported that long-day conditions produced rapid and high hatching rates (61…97%) in PCN populations.

Sometimes in this experiment the first non-host crop grown after potato reduced the PCN population density slightly more than the following crops but, because of the large variation in nematode population density estimates the difference between the first and other non-host crops was statistically insignificant.

The use of the nematicide did not completely control multiplication of the nematode when susceptible potatoes were grown. An unsatisfactory effect of oxamyl on PCN multiplication has also been found in other field studies (Whitehead *et al.*, 1994). In practice, this result means that if control of yield losses is based on the use of oxamyl there will be a continuous need for the nematicide because nematode populations stay above economical thresholds. Oxamyl treatments did increase yields of the susceptible cultivar as found in other experiments (e.g. Whitehead *et al.*, 1994) but this results does not suggest that there is a need to have nematicides registered for control of PCN in the Finnish climatic conditions.

The large decline of population density and cyst contents of the nematode in 1987 showed clearly that in Finland the shortness of growing season may often limit the pest potential of plant parasitic nematodes. In northern parts of the country the phenomenon is even more distinct, helping to keep the area of seed potato production free of PCN. In Finland the cold year 1987 was critical for many other pests, too (Tuovinen, 1992).

The effect of soil borne diseases were not analysed in the experiment. Thus the yield results presented here may include the complex stress caused by PCN and soil borne diseases which are normally found in field conditions (e.g. Mazurkiewicz *et al.*, 1994).

The quite dramatic decline of yields in monoculture cropping of susceptible potatoes showed that PCN can cause severe losses in Finland if the farming system is not planned to be sustainable. On the other hand, even a relatively short crop rotation seems to provide the opportunity to avoid the whole problem. The effect of crop rotation on potato yields in this experiment was in good agreement with results of an experiments done in northern Poland (Rzeszutek, Zawislak, 1995). Yields of the resistant potato were also very similar, and the relationship between potato yield and initial population density (Pi) was as generally reported (Trudgill *et al.*, 1987).

In the future, predicted global warming may increase the pest potential of PCN and other plant parasitic nematodes in northern Europe (Mela *et al.*, 1996). If this occurs, it will be important to study soil supressivenes by which PCN can be kept under control. Plant health-promoting rhizobacteria, fungi, and other mycoflora may have an essential role in the integrated control of PCN and sustainable production of potatoes.

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KOKKUVÕTE. Kartulinematoodi Globodera rostochiensis integreeritud tõrje Soomes. *Lõuna-Soomes uuriti aastatel 1981…1991 külvikorra mõju kartulinematoodile Globodera rostochiensis ja kartuli saagikusele. Katsetati kuut erinevat viljelussüsteemi. Kartuli monokultuuriga lappidel langes mugulasaak 35-lt 4,6-le t/ha. Viljelussüsteemide puhul, kus kartulit kasvatati iga 5, 4 või 3 aasta järel, jäi saak esialgsele tasemele. Vastuvõtliku kartuli kasvatamine tõstis nematoodi tihedust 0,1-lt 265-le munale 1 g mullas nelja aasta jooksul. Pärast seda kõikus tihedus 25 ja 136 muna vahel. Nematooditõrje (oksamüül) ei pidurdanud nematoodi paljunemist, kuid vähendas saagikadusid. Resistentse kartuli (H1) kasvatamine vähendas nematoodi populatsiooni 80% võrra ja mitteperemeestaim (kaer) vähendas seda keskmiselt 60% võrra. Soovitada võiks kartuli viljelussüsteemi üks kord iga kolme aasta järel, vaheldumisi resistentne ja vastuvõtlik vorm.*