Population Changes of the Potato Cyst Nematode (*Globodera rostochiensis*) during Irregular Crop Rotation

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Abstract

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For a period of 17 years, changes in the number of potato cyst nematode (PCN) cysts in the soil and in their contents were studied in two fields with an irregular crop rotation and growing resistant and susceptible potato cultivars. In all years, the numbers of cysts per 100 g of soil were higher at Skorkov (S) than at Otradovice (O). At the beginning of the experiment, the percentages of empty PCN cysts were 30 and 28%, respectively, but they increased to 92.5 and 94.6%, respectively, by the end of it. The remaining cysts contained dead eggs/larvae and empty egg cases. Thus, the number of cysts per 100 g of soil cannot be used to estimate the degree of soil infestation with the PCN without also knowing the number of viable stages in the cysts. When the experiment started the mean number of viable eggs/larvae per cyst was 62.7 in field S and 51.3 in field O; no viable stages of the pest were found at the end of the experiment. Parallell to the decline in the number of viable eggs/larvae per cyst, the numbers of cysts with viable contents also declined in both fields. The mean number of dead eggs/larvae per cyst showed considerable variation in the course of the experiment. In field S it varied within a range of 15.9–69.4 individuals per cyst. Over the years the number of empty egg cases per cyst showed an irregular increasing trend. In field S their number varied from 34.9 to 197.5 per cyst. In field O from 46.3 to 218. No unequivocal negative effect of cropping resistant potato cultivars on the number of PCN cysts in the soil has been ascertained. In most years, the cropping of resistant cultivars was followed by an increased number of empty cysts in soil samples in both experimental fields. The effect of growing resistant cultivars on the number of viable eggs/larvae was negative in both fields, resulting in decreased mean numbers of viable individuals per cyst. The mean number of dead eggs/larvae per cyst was variable. The number of empty egg cases was usually higher after the harvest of a resistant potato cultivar. The numbers of empty cysts and those with dead contents increased distinctly after an application of pig manure prior to growing the resistant cultivar and in subsequent years. The mean number of cysts in the soil, and of viable stages in the cysts also declined after a crop of rye. Regular cropping of resistant potato cultivars at 3-year intervals, once interrupted by growing a susceptible plant cultivar, decreased the occurrence of viable stages of the PCN below the detectable level.

Key words: potato; *Globodera rostochiensis*; crop rotation; resistant cultivars; population density; cyst content; Czech Republic

The potato cyst nematode (*Globodera rostochiensis*) (hereafter PCN) is a pest specialised to potatoes as its major host plant. This pest causes losses of yields especially in localities in which regular crop rotation is not maintained. Besides losses in yields, the nematode is also troublesome by causing difficulties in maintaining phytosanitary measures connected with the prohibited cropping of seed potatoes and regulated distribution of table potatoes. In Europe the contemporary ways of protection against the PCN are mainly aimed at a 3 to 5-year crop rotation and to combin such a rotation with growing resistant potato cultivars. In integrated pest management, the growing of resistant potato cultivars is combined with partial use of nematocides.

The goal of this study was to find out, in a long-term field experiment carried out under specific conditions of an early potato growing region, the variation in the density of cysts of the PCN in the soil, their contents and the occurrence of live eggs/larvae per cyst. Ultimately, the study was to show that through repeated growing of resistant potato cultivars and crop rotation, the occurrence of live developmental stages of the pest below the level of detection by means of the flotation method .

MATERIAL AND METHODS

In 1977–1993 the experiments were carried out in central Bohemia on an agricultural enterprise specialised in growing early potatoes and field vegetables. Two fields infested with the PCN, pathotype Ro_1, were selected: at Skorkov (S, 0.3 ha) and Otradovice (O, 0.4 ha); they were 2 km apart. Both localities lie in the warm climatic region, and in its warm, moderately dry district (A_3), and have a mild winter. The annual mean air temperature is 8.5°C, the average annual precipitation is 554 mm. During the growing season the mean air temperature is 14.5°C, the average rainfall 365 mm. In pedogenetical respect the soil of the fields is loamy-sand to sandy-loam with a humus layer 0.2–0.3 m deep. The subsoil consists of sands passing to gravelly sands. The groundwater level is 8–10 m deep. The hydrolimits are 24.4% in field capacity, 8.3 % in the wilting point, and 16.1% in utilizable water capacity. The pedological characteristics of the localities and the hydrometeorological data have been supplied by the Skorkov station of the Research Institute for Soil and Water Conservation.

The crop rotation in the experimental fields was irregular, with resistant potato cultivars been grown at mostly three-year intervals. The cultivars changed in the course of the experiments. In all, five resistant cultivars and two susceptible ones were used (Table 1). Fertilisers were applied according to a planned supplementary fertilisation regime of the individual crops. Organic manure was applied in a dose of 40 t/ha of pig manure in the spring of 1983. The potatoes were grown in rows 0.65 m apart. At locality S the susceptible potato cultivar Aquila was last cropped in 1975, while at locality O a susceptible cultivar was still cropped in 1977.

Soil samples were taken every year at nine fixed points in each field. This was done after harvest, and invariably before the post-cropping soil preparation for the subsequent crop. The samples were taken using a sampler 100 × 100 × 150 mm. Prior to analysis the samples were air-dried for 3 days at 20°C. From each field, cysts of the PCN were obtained from the nine soil samples by flotation on a Fenwick can. The maximum, minimum and mean number of cysts in each of the samples were determined; microcysts were not included in the total number of cysts. From each of the nine samples taken in each of the fields, 10 large spherical cysts were removed, individually crushed in a drop of water on a slide, and the number of viable and dead eggs/larvae and that of empty egg cases per cyst were determined using a projection microscope. The viable and dead eggs/larvae were differentiated by staining with malachite green (0.5%) for 2 h. Eggs/larvae with a greenish colour were taken as viable, while dead ones were brown; dead larvae were often curved in a triangular form.

RESULTS

The experimental fields were infested with the PCN to varying degrees. The mean infestation at locality S during the 17 years was 254.7 cysts per 100 g of soil, with a minimum of 80 and maximum of 550 cysts. The number of cysts per sample showed considerable variation; still in 1988 there was a mean of 313.7 cysts per sample. In that year, too, the highest number of cysts in a sample was determined, amounting to 550. The number of cysts per sample showed the widest variation in 1977 through 1983, a decline in the numbers of cysts paralleled the years in which resistant potato cultivars were grown. In those years, too, the number of cysts below the means per sample increased. In years following the cropping of resistant potato cultivars the number of cysts increased in most cases. The greatest decline in the number of cysts was observed in 1983 after pig manure was applied and a resistant potato cultivar was grown. In 1986, after a susceptible cultivar had been cropped, the number of cysts per sample increased temporarily. From 1989 to the end of the experiment the mean number of cysts per sample showed an almost uniform decline (Fig. 1).

At locality S the percentage of empty cysts increased from 30 to 59.8% from 1977 to 1982. In 1983, after the spring

Table 1. Crop rotation on the experimental fields in Skorkov (S) and Otradovice (O) 1977–1993

Year	Locality		Year	Locality	
	Skorkov	Otradovice		Skorkov	Otradovice
1977	potato cv. Sagita	potato cv. Aquila	1986	potato cv. Resy	potato cv. Resy
1978	rye	rye	1987	rye	winter rape
1979	maize	potato cv. Gloria	1988	winter rape	onion
1980	potato cv. Gloria	carrot	1989	potato cv. Premiere	potato cv. Ausonia
1981	winter wheat	winter wheat	1990	carrot	maize
1982	onion	maize	1991	winter barley	winter barley
1983	potato cv. Ausonia	potato cv. Ausonia	1992	potato cv. Impala	potato cv. Impala
1984	maize	rye	1993	maize	fallow
1985	carrot	carrot			

application of pig manure and cropping of the resistant potato cultivar Ausonia, this percentage increased to 79%. In subsequent years the percentage of empty cysts increased, attaining a maximum of 98% in 1992. The numbers of empty cysts increased markedly in years in which a resistant cultivar was grown. In contrast, the number of empty cysts decreased after a susceptible cultivar had been cropped in 1986 (Fig. 1). The mean number of viable eggs/larvae per cyst decreased irregularly from 1977 to 1984. At the beginning of the experiment this number was 62.7; after 1983 the number of viable eggs/larvae per cyst did not decrease markedly until 1989. In 1986, when a susceptible cultivar was grown, the number of viable individuals per cyst increased and did not decline until after a resistant cultivar was cropped in 1989. During the 17 years of observations the number of cysts containing viable eggs/larvae decreased gradually. In 1977, of the 90 examined cysts 85 contained viable eggs/larvae; 70 in 1982; 60 in 1983; 18 in 1987; only two cysts with viable content were found in 1992; and none in 1993.

From 1977 to 1983 the number of dead eggs/larvae per cyst varied from 21.5 to 81.6. In 1984 it increased to a maximum of 93.4. After that year it showed an irregular decreasing trend, and in 1993 there were 41.8 dead eggs/larvae per cyst. The least number of empty egg cases per cyst was observed from 1979 to 1982 and in 1986. In the other years of the experiment the number of empty egg cases varied above 100 up to a maximum of 197.5 in 1987. In 1977 a cyst was found containing the maximum number of 327 viable embryos/larvae and 17 dead ones. In 1991, at the same locality, a cyst was found containing 598 dead embryos/larvae. HESLING (1959) had found a cyst with 765 eggs.

The field at locality O was less infested with the PCN than that at S. The mean number of cysts per 100 g of soil was 163.6 cysts during the 17 experimental years. The highest number of cysts found in a soil sample was 460 in the first year; the lowest number of 72 cysts was found in a sample in 1982. The mean number of cysts per 100 g of soil decreased markedly from the beginning of the experiment until 1984. A marked decline in the number of cysts occurred after the application of pig manure and cropping of the resistant potato cultivar Ausonia in 1983. Since that year until the end of the experiment in 1993 the mean number of cysts decreased slowly, except in 1986 when a susceptible cultivar was grown in that field, and in 1993 when it was fallow. In 1977 the percentage of empty cysts was 28 %; it increased to 80% by 1983, and from 1984 on it increased with slight oscillations to 94% in 1993 (Fig. 2). The mean number of viable eggs/larvae per cyst was 51.3 at the start of the experiment; by 1983 it had decreased to 13 individuals, and the number of viable stages decreased further from 5.1 in 1984 to 0.98 in 1992. In 1993 no cysts with viable contents were found. Viable eggs/larvae were found in 82 out of the 90 cysts in 1977; in 65 in 1982; 52 in 1983; 12 in 1987; 2 in 1992, and no viable eggs larvae were found in the cysts in 1993. In successive years of the experiment, the mean number of dead eggs/larvae per cyst

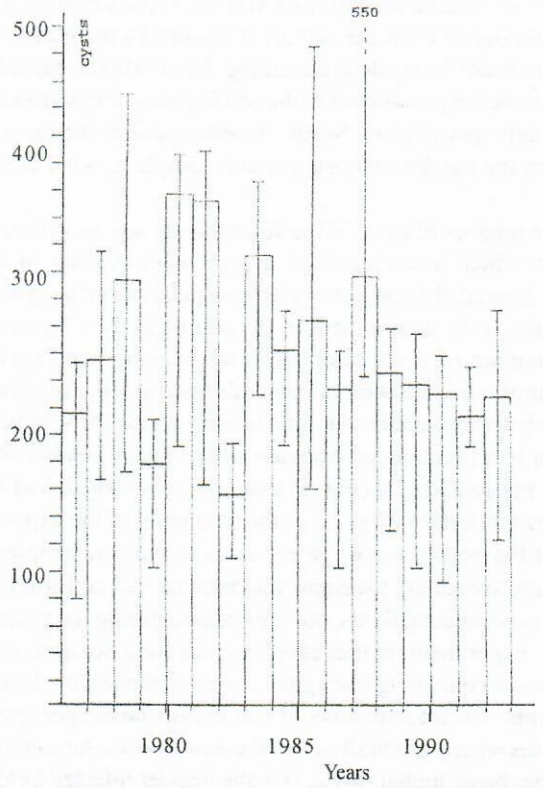

Fig. 1. Changes in the numbers of cysts between 1977–1993 (Skorkov = S)

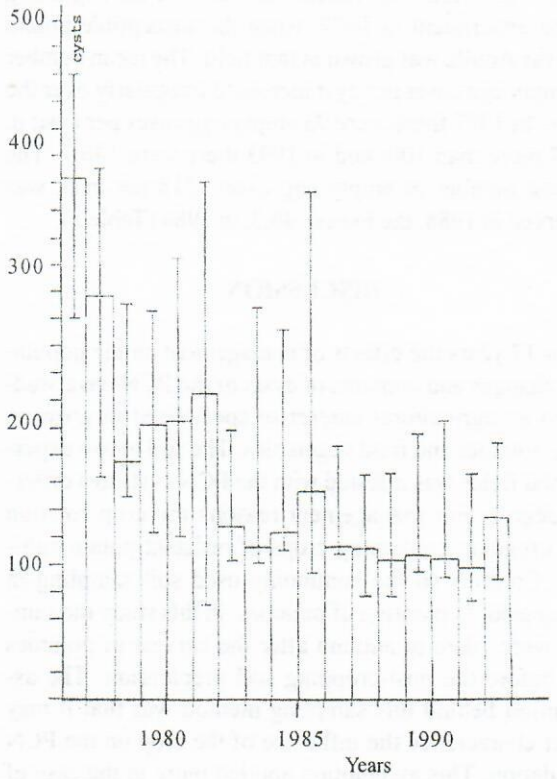

Fig. 2. Changes in the numbers of cysts between 1977–1993 (Otradovice = O)

Table 2. Changes in content of cysts between 1977–1993 (Skorkov and Otradovice)

Year	Skorkov				Otradovice			
	% of empty cysts	average number of eggs/larvae per cyst		empty cases of eggs	% of empty cysts	average number of eggs/larvae per cyst		empty cases of eggs
		viable	dead			viable	dead	
1977	30.0	62.7	72. 0	109.7	28.0	51.3	16.8	93.0
1978	43.0	48.0	76.6	133.0	34 2	38.8	59.2	81.0
1979	54.0	49.7	74.1	62.8	56.7	22.9	37.4	61.2
1980	63.0	59.9	81.6	34.9	63.3	24.6	62.5	56.1
1981	60.0	49.7	74.2	62.8	81.3	41.9	49.6	62.8
1982	59.8	42.4	21.5	91.6	66.4	26.1	48.6	67.0
1983	79.0	27.1	61.1	101.4	80.1	13.0	69.4	53.6
1984	81.2	23.6	93.4	184.0	87.8	5.1	39.3	46.3
1985	74.0	24.3	62.0	48.0	81.0	3.6	15.9	49.3
1986	61.0	28.5	33.3	64.2	87.0	4.6	17.5	78.2
1987	84.0	25.5	74.1	197.5	89.2	3.2	49.2	190.2
1988	83.0	18.8	45.2	156.4	73.0	3.1	68.4	218.0
1989	91.1	8.10	49.7	178.0	87.5	2.4	54.6	189.0
1990	95.6	0.91	42.8	191.3	79.3	0.0	37.4	179.3
1991	95.6	0.72	47.2	123.0	85.0	0.03	21.3	144.4
1992	98.0	0.04	67.9	171.8	83.9	0.98	21.0	138.6
1993	92.5	0.00	41.8	182.6	94.6	0.0	30.5	146.7

varied from 16.8 (in 1977) to 69.4 (in 1983). The low number of 16.8 dead individuals was found at the beginning of the experiment in 1977, when the susceptible potato cultivar Aquila was grown in that field. The mean number of empty egg cases per cyst increased irregularly over the years. In 1977 there were 93 empty egg cases per cyst; in 1987 more than 100; and in 1993 there were 146.7. The highest number of empty egg cases, 218 per cyst, was observed in 1988; the lowest, 46.3, in 1984 (Table 2).

DISCUSSION

For 17 years the effects of management on the population changes and contents of cysts of the PCN were studied in an agricultural enterprise specialised in growing early potatoes and field vegetables. The soil in two experimental fields was infested with the PCN cysts to a different degree. For management reasons the crop rotation was irregular, containing crops of resistant potato cultivars. Contrary to the commonly used soil sampling in spring prior to planting of potatoes, in this study the samples were taken in autumn after the harvest of potatoes and before the post-cropping soil preparation. The assumption behind this sampling method was that it may better characterise the influence of the crop on the PCN population. This assumption applied more in the case of crops with root systems penetrating down to a depth of 150 mm. It was less suitable with deeper rooting potato crops. According to WHITEHEAD (1995) the variation in the number of cysts per sample is caused by the translocation of soil during deep ploughing. It may also be caused by the uneven penetration of the soil in potato crops grown in widely spaced rows. SEIDEL (1996) ascribes the variation in the number of cysts per soil sample to wind erosion.

The number of cysts in the soil samples was no criterion by which to estimate the degree of infestation of a field. Instead, the number of viable eggs/larvae in the cysts had also to be determined. In the course of the 17 years the number of cysts sampled at unchanging stationary sampling sites showed considerable variation. In field S, with a heavy and insular infestation with the PCN, there was a less pronounced decrease of the mean number of cysts per soil sample (Fig. 1) than in field O which had a lighter infestation (Fig. 2). At the beginning of the experiment the occurrence of empty cysts in the soil samples was approximately the same and more or less uniform in both experimental fields, but it increased during the years of the experiment. In that case the cysts were not divided into those containing live eggs/larvae and those with dead contents. The mean number of viable eggs/larvae per cyst also decreased gradually over the years, with the initial number being higher (at 62.7) in the heavier infested field S than in the less infested field O (at 51.3). In subsequent

years the mean number of viable individuals per cyst showed a different decline, depending on the different degree of infestation of the two fields. In the heavier infested field S a marked decline did not occur until 1989, in the less infested field O already in 1984. Contrasting results have been obtained by COOPER (1953), WHITEHEAD (1995) and others who have found that the degree of the decline in the number of viable eggs/larvae is independent of the initial density of the PCN population. The authors have proved, however, that the rate of the decline differs in light and heavy textured soils. In our experiments, carried out in a soil of loamy sand, the number of cysts with viable contents was found to decline in correlation with the mean number of viable individuals per cyst.

In 1983 pig manure was applied to both experimental fields in spring prior to planting a resistant potato cultivar. In that year, after the harvest of potatoes, the mean number of viable eggs/larvae in the soil samples taken in field S had declined from 42.4 to 27.1, in field O from 26.1 to 13. In the subsequent 5 years the number of viable eggs/larvae declined, though negligibly in the heavily infested field S, and dropping to zero only after two crops of resistant potato cultivars (in 1989 and 1992). In the less infested field O the number of viable individuals per cyst declined distinctly in the years after the application of pig manure, and dropped to zero in 1990 for the first time. It may be assumed that the effect of pig manure on the PCN population was due to the high content of ammonia in the manure and to increased microbial activity in the soil, or to the combined effect of multiplied microbial populations and their impact on the hatching of the PCN as well as of root exudates of the resistant potato cultivar. According to WHITEHEAD *et al.* (1972) the hatching of PCN larvae and their invasion of roots may also be affected by planting time. Hatching is higher after an early planting, a part of the PCN population will reproduce, survive to the subsequent years and may be the cause of an increased occurrence of the PCN. BRZESKI *et al.* (1971) found no influence of industrial and organic fertilisers on the PCN population. MCSORLEY and GALLAGHER (1997) however, observed a reducing effect of yard waste compost on the nematode *Paratrichonotus minor*, particularly if the application was repeated.

During the 17 experimental years the number of dead eggs/larvae per cyst varied in field S between 21.5 and 94.3, in field O between 15.9 and 69.4. The variation was not correlated with the decline in the number of viable individuals nor with the growing of resistant potato cultivars. The number of empty egg cases per cyst was usually higher following crops of resistant potato cultivars. Five resistant potato cultivars were grown in fields S and O during the experiment. The degree of their resistance, tolerance or susceptibility was not tested. These cultivars may have affected the density of the PCN population in different ways. Older resistant cultivars are known to have a lower degree of resistance, and cysts with viable contents may have developed on their roots and be part of the variation in the occurrence of the PCN. The number of viable stages increased temporarily after a susceptible potato cultivar was grown in 1986. In Finland, TILLIKKALA (1991) found that growing a susceptible potato cultivar once in 4-5 years, or alternate growing of a resistant and a susceptible cultivar at intervals of 3 years, decreased the PCN population density below the threshold of economic importance or below the detectability level. In our experiments with a 3-year interval of growing resistant potato cultivars, interrupted by 1 year of a susceptible one, the density of the PCN population was decreased below the detectability level of viable stages of the PCN. This result supports the conclusions of SEIDEL (1996) who does not recommend to exclusively grow resistant potato cultivars, as it increases the risk of selecting PCN populations having different degrees of virulence. The author recommends as more suitable to alternately grow a resistant and a susceptible cultivar. Finally, the results reported above may not be generally valid. MUGNIÉRY (1982) has suggested that each PCN population may be considered as a separate ecotype, and the effect of crop rotation must be studied locally in each of the potato growing regions.

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Souhrn

ŠEDIVÝ J. (1999): **Změny populace háďátka bramborového (*Globodera rostochiensis*) v nepravidelném střídání plodin**. Pl. Prot. Sci., **35**: 125–130.

Na dvou lokalitách ve středních Čechách s nepravidelným střídáním plodin a pěstováním rezistentních odrůd brambor byly po dobu 17 roků zjišťovány změny v počtu cyst háďátka bramborového v půdě a v jejich obsahu. Na lokalitě Skorkov (S) byl po celou dobu trvání pokusů počet cyst vyšší než na lokalitě Otradovice (O). Na počátku pokusu bylo 30 a 28 % prázdných cyst, na konci pokusu 92,5 a 94,6.%. Ve zbytku cyst byla zjištěna mrtvá vajíčka/larvy a prázdné obaly vajíček. Počet cyst na 100 g půdy nelze využít k hodnocení stupně zamoření půdy, bez zjištění živých stadií škůdce v cystách. Počet živých vajíček/larev na počátku pokusu byl v S průměrně 62,7 jedinců na cystu, v O 51,3 kusů na cystu, na konci pokusu nebyla živá stadia zjištěna. Současně s poklesem živých vajíček/larev na cystu klesal na obou lokalitách počet cyst s živým obsahem. Průměrný počet mrtvých vajíček/larev na cystu se během pokusu značně měnil. Na pozemku S se pohyboval v rozmezí od 21,5 do 93,4 jedinců na cystu a na pozemku O od 15,9 do 69,4 jedinců na cystu. Počet prázdných vaječných obalů na cystu měl během pokusů nepravidelnou vzestupnou tendenci. Na lokalitě S se jejich počet pohyboval od 34,9 do 197,5 kusů na cystu, na pozemku O bylo zjištěno 46,3 až 218 vaječných obalů na cystu. Jednoznačný negativní vliv pěstování odolných odrůd na počet cyst v půdě nebyl zjištěn. Počet prázdných cyst se po pěstování odolných odrůd ve většině roků na obou pozemcích projevil zvýšeným zastoupením prázdných cyst v půdních vzorcích. Vliv rezistentních odrůd na počet živých vajíček/larev byl na obou pozemcích negativní, projevil se snížením průměrného počtu živých jedinců na cystu. Pokles živých jedinců na cystu byl vyšší na slaběji zamořeném pozemku. Průměrný počet mrtvých vajíček/larev na cystu byl značně proměnlivý, neměl zřetelný vztah k pěstování rezistentních odrůd. Počet prázdných vaječných obalů po pěstování rezistentní odrůdy byl převážně vyšší. Početnost prázdných cyst a jejich mrtvého obsahu se výrazně zvýšila po aplikaci prasečího hnoje před pěstováním rezistentní odrůdy a v následujících letech. Průměrný počet cyst v půdě a živých stadií škůdce v cystě se snížil také po pěstování žita. Pravidelným pěstováním odolných odrůd v tříletém intervalu, jednou přerušeném pěstováním náchylné odrůdy, se výskyt živých stadií háďátka bramborového za 17 roků snížil pod hranici detekce.

Klíčová slova: brambory; *Globodera rostochiensis*; střídání plodin; rezistentní odrůdy; denzita populace; obsah cyst

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