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Resistance of potato varieties to field populations of the potato cyst nematode Globodera pallida in the northeastern part of the Netherlands

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Abstract

In the northeastern part of the Netherlands starch potatoes are grown intensively. From 392 fields in that area, soil samples that contained the potato cyst nematode *Globodera pallida* were used to analyze the resistance of 7 varieties of starch potatoes.

Differences and similarities in resistance of the varieties to the field populations of *G. pallida* could well be explained by their descent from distinct sources of resistance.

The *G. pallida*-populations that showed a relatively high virulence to the varieties Producent, Elles, and Darwina were not equally distributed over the area, but were confined to a small number of regions.

Additional keywords: geographic distribution, virulence.

Introduction

In the northeastern part of the Netherlands starch potatoes have been grown intensively in a rotation scheme of 2 or 3 years. This narrow rotation has enhanced yield loss due to potato cyst nematodes (*Globodera rostochiensis* and *G. pallida*). Before 1975, *G. rostochiensis* predominated, but later, when varieties were grown that were resistant to *G. rostochiensis*, *G. pallida* emerged (Mulder and Veninga, 1988).

At least 6 'pathotypes' of the 2 *Globodera* species together can be distinguished in the Netherlands, based on their different abilities to reproduce on various potato varieties (Kort et al., 1977). In the Netherlands each potato grower could request, at the Laboratory for Soil and Crop Testing in Oosterbeek, determination of the cyst density and of the pathotype in his field. The potato grower combined this information with data on resistance, in order to choose the most suitable potato varieties. However, the pathotype scheme of Kort et al. (1977) for *G. pallida* has been criticized strongly (Phillips and Trudgill, 1983; Bakker, 1987; Nijboer and Parlevliet, 1990). Populations of *G. pallida* that belonged to the same pathotype according to the conventional scheme, differed distinctly in virulence (Dellaert and Vinke, 1987). Therefore the pathotype scheme reflected the virulence of *G. pallida* populations unsatisfactorily.

This doubt about the appropriateness of the conventional grouping of populations of *G. pallida* according to virulence, together with the rise of *G. pallida* in the field, resulted in replacement of determinations of pathotypes by 'varietal tests'. For a varietal test, soil from a contaminated field is sampled, and the reproduction of the potato cyst nematodes from this soil is examined for a set of commonly grown varieties. The varietal test passes over any pathotype classification, but it provides relevant information about resistance of varieties to the concerning field population (Mulder et al., 1991).

During 1988–1990, hundreds of these varietal tests were carried out for the north-east of the Netherlands, at Oosterbeek. The data from these tests were analyzed statistically to gain insight into resistance of the tested varieties to the field populations of *G. pallida*.

Materials and methods

Sampling of fields. When a farmer requested an estimate of the cyst density, his field was divided into plots of half a hectare which were sampled. Cysts were counted after elutriation. For an additional varietal test a second sample of 4 liters of soil was taken, usually from the most contaminated plot of the field, by taking 40 spits of 100 ml at regular intervals over the plot.

Varietal test. Each sample was mixed and put into transparent plastic containers of 125 ml. Potato tubers with diameters of 25 to 28 mm were then put into the containers, one tuber for each container. Tubers of 7 varieties were tested in triple, resulting in 21 containers for each soil sample. To reduce evapotranspiration but still allow some aeration, the containers were closed with perforated caps. After 8 to 12 weeks of incubation at 20 °C, the newly formed cysts that were visible on the roots from the outside of the transparent containers were counted.

The 7 varieties used and their resistance are presented in Table 1. In the Dutch descriptive list of varieties of field crops (CPRO-DLO, 1992), a potato variety is called resistant to a pathotype of *Globodera* if $P_f/P_i < 0.2$, where P_i represents the number of cysts of the considered pathotype per mass of soil at inoculation time, and P_f the number of new cysts per mass of soil after one generation of the potato cyst nematodes. A variety is called susceptible when the quotient is > 0.65.

A small fraction (less than 5 percent) of the samples contained *G. rostochiensis*; these were determined by the criterium: new cysts on the susceptible var. Mentor but none on the var. Elkana. The differential 'Elkana' is resistant to *G. rostochiensis* but susceptible to

Table 1. Set of varieties of starch potatoes, used in the varietal test and ratings for resistance according to the Dutch descriptive list of varieties of field crops; pathotypes of *Globodera rostochiensis* (Ro) and of *G. pallida* (Pa) according to Kort et al., 1977.

Variety	*Globodera rostochiensis*[1]				*Globodera pallida*[1]	
	Ro1	Ro2/3	Ro4	Ro5	Pa2	Pa3
Mentor	+	+	+	+	+	+
Saturna	–	+	–	+	+	+
Astarte	–	+	+	+	+	+
Elkana	–	–	–	+	+	+
Producent	–	–	–	–	±	+
Elles	–	–	–	–	–	+
Darwina	–	–	–	–	–	+

[1] + = susceptible; – = resistant; ± = small susceptibility.

G. pallida (Table 1). These field samples were left out for further analysis, as well as samples that had missing values in the varietal tests. This led to 392 samples available for the analysis presented here.

Data conversion. The triple counts were averaged, giving as smallest statistical unit: 'number of new cysts counted for each combination of variety and field population of *G. pallida*, averaged over three containers' (N). The quantity N showed a strong variation. This strong variation was caused by several factors:

1. Variation in density of vital larvae in the soil at the beginning of the varietal tests;
2. Differences in properties of the sample soils;
3. Differences in levels of resistance of the varieties, averaged over the 392 *G. pallida* populations;
4. Differences in population-specific resistance of the varieties and in virulence of the populations of *G. pallida*;
5. Other factors causing 'experimental noise'.

To adjust for variation in density of the inoculum and for differences in soil properties (factors 1 and 2), N was divided by the N of the susceptible variety Mentor. The underlying assumption is that the ratio (N / N_{Mentor}) is almost constant for a wide range of inoculum densities and for the different sampled soils, for a given variety and a given *G. pallida* population (Phillips and Trudgill, 1983; Seinhorst and Oostrom, 1984).

Several transformations of the ratio were compared with respect to distribution and power in differentiation between (groups of) samples. The square root transformation led to the best differentiation, least skewness and best approximation to normal distributions, so analysis was based on

$$x = \sqrt{\frac{N}{N_{\text{Mentor}}}}$$

Resistances of the varieties. Figures for levels of resistance were obtained by averaging x per variety, pooling all 392 populations of *G. pallida*. Differences between the 6 varieties and relationships among them were studied by applying principal component analysis.

Geographic distribution of virulent G. pallida-populations. We analyzed the frequency-distribution and intervals within it, of the mean relative reproduction for the 6 varieties and especially for 'Producent', 'Elles' and 'Darwina', in relation to the geographic distribution.

We studied whether *G. pallida*-populations within the distinguised intervals and especially *G. pallida*-populations that showed a high virulence to the varieties Producent, Elles, and Darwina were randomly spread among the sampled fields or according to a geographic pattern. The locations of the fields were described by the coordinates of the municipalities in which the fields were situated. The area was split up into longitudinal and transverse zones which contained as far as possible the same number of fields. Use was made of χ^2-tests to test whether the relative frequencies of the extra virulent populations per zone were the same for all zones.

Results

Average resistance of the varieties. The varieties differ clearly ($P < 0.001$) in resistance to the field populations of *G. pallida* (Table 2). Of the total variation in x, (where variation

Table 2. Mean relative resistance of varieties of starch potatoes to 392 field populations of *Globodera pallida* from the Dutch starch potato area.

Variety	Average number of new cysts relative to variety Mentor	
	after √-transformation*	without √-transformation
Mentor	1.00	1.00
Saturna	0.94	0.92
Astarte	0.79	0.68
Elkana	0.74	0.59
Producent	0.47	0.25
Elles	0.37	0.17
Darwina	0.28	0.11

* All values differ significantly from one another by Student's paired t-test ($P = 0.01$).

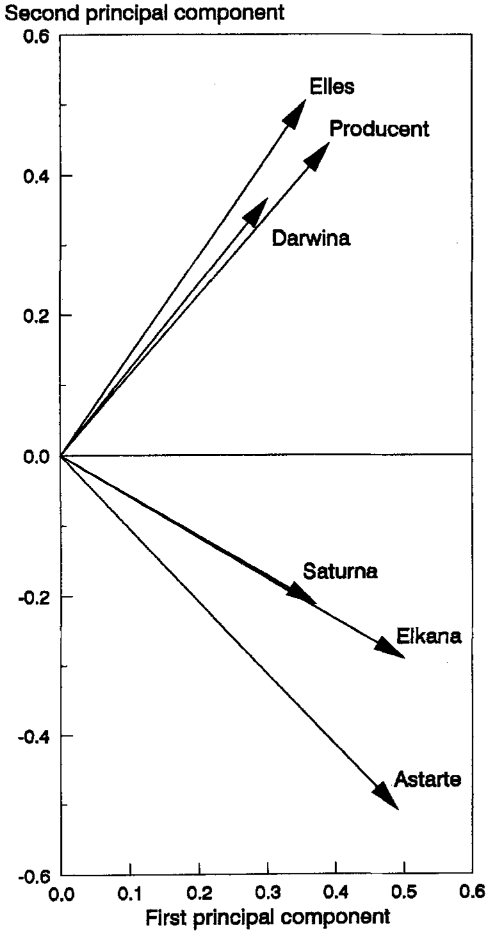

Fig. 1. Representation of the varieties as vectors in a two-dimensional space with the first two principal components as axes.

in x is defined here as sums of squares of differences in x), 60% could be assigned to differences in the average levels of resistance of the varieties.

Similarities and contrasts between the varieties. In Fig. 1 the 6 varieties are projected in a plane formed by the first and the second principal components, which respectively explained 51% and 16% of the variance. According to Fig. 1 the varieties can be divided into two major groups of varieties: the first group consists of varieties Producent, Elles and Darwina, and the second group is composed of varieties Saturna, Elkana and Astarte. The latter group may be subdivided into a group that contains 'Saturna' and 'Elkana', and a group that consists of 'Astarte' only.

Geographic distribution of virulent G. pallida-populations. For most of the populations there was no correlation between the distribution of virulence and the geographic distribution.

An exception was a group of 33 populations that showed the highest relative reproduction on all 6 varieties and especially on the 3 varieties Producent, Elles, and Darwina. The mean reproduction over these 3 varieties, in new cysts relative to 'Mentor', was between 0.30 and 0.67. The mean reproduction, averaged over the 33 populations, was: 0.46; this average was separately for varieties Producent, Elles and Darwina respectively 0.58, 0.48, and 0.32. Probably those populations were more virulent to these varieties than the other populations. The tests for the 33 populations gave a highly significant effect ($P = 0.01$), meaning that the populations were not equally distributed over the zones, but restricted to clusters of locations. These clusters do not represent a specific type of soil. The geographic distribution is depicted in Fig. 2. An explanation for the pattern of this distribution was not found.

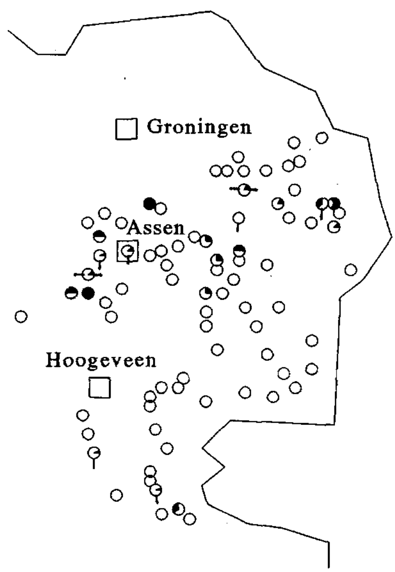

Fig. 2. Geographic distribution of 33 *Globodera pallida*-populations that showed a high virulence to the varieties Producent, Elles, and Darwina. For each municipality a segment diagram is drawn. Each black segment represents the number of fields that contain the more virulent populations in a municipality, relative to the total number of screened fields with *G. pallida* in that municipality. Rectangle: for orientation; two bars: municipality with > 30 fields; single bar: 11–18 fields.; no bar: 1–8 fields.

Discussion

Similarities and contrasts between the varieties. Although the varieties Producent, Elles, and Darwina differ significantly in level of resistance (Table 2), they look similar according to the principal component analysis (Fig. 1). This may be caused by similarity with respect to vertical resistance although there are differences in horizontal resistance (Vanderplank, 1969). The similarity in vertical resistance may be related to the fact that the 3 varieties all descend from the *Solanum vernei* hybrid SVP$(VT^n)^2$ 62.33.3. This genotype is the differential used to discriminate between Pa2 and Pa3 in the pathotype scheme of Kort et al. (1977), and inherently contains vertical resistance.

In the breeding program of Saturna and Elkana the genotype CPC 1673-1 was used for resistance to *G. rostochiensis*, but Astarte descends from the *G. rostochiensis* resistant *Solanum vernei* hybrid VT^5 62-69-5. Plausibly, these 2 genotypes have distinct effects on resistance to *G. pallida* in their offspring, as is also indicated by the principal component analysis (Fig. 1).

Significance to potato growing and breeding. There are many rather virulent populations in the area and in some regions even populations with a very high virulence (Fig. 2). Unfortunately the populations that are relatively virulent to 'Darwina' are virulent to 'Elles' and 'Producent' as well. This implies that the selection pressure of these varieties on *G. pallida* is similar. All these varieties push the *G. pallida*-populations to the same virulence properties. For that reason alternation of varieties Elles, Darwina, and Producent to prevent or retard break down of resistance will be not effective. For an effective alteration that leads to durable resistance, varieties are needed that have more complementary resistance spectra. Therefore there is an urgent need at the moment of new varieties that are resistant to populations that are virulent to varieties Darwina and Elles.

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References

Bakker, J., 1987. Protein variation in cyst nematodes. Dissertation, Wageningen Agricultural University. Ponsen & Looijen, Wageningen, the Netherlands. 159 pp.

CPRO-DLO, 1992. 67e Beschrijvende rassenlijst voor landbouwgewassen 1992. Leiter-Nijpels, Maastricht. 336 pp.

Dellaert, L.M.W. & Vinke, J.H., 1987. Testing potatoes for resistance to *Globodera pallida* pathotype Pa-3; resistance spectra of plant genotypes and virulence spectra of Pa-3 isolates. Revue de Nematologie 10: 445–453.

Kort, J., Ross, H., Rumpenhorts, H.J. & Stone, A.R., 1977. An international scheme for identifying and classifying pathotypes of potato cyst-nematodes *Globodera rostochiensis* and *G. pallida*. Nematologica 23: 333–339.

Mulder, A. & Veninga, G., 1988. Praktijkonderzoek naar het verloop van het besmettingsniveau van het aardappelcysteaaltje en haar pathotypen in het Noordoostelijk Zand- en Dalgrondgebied. Eindverslag van het Federatieonderzoek over de periode 1968–1986. H.L. Hilbrandslaboratorium voor Bodemziekten. Verslagnr. HLB 88-2. 17 pp.

Mulder, A., Roosjen, J. & Veninga, G., 1991. Rassenkeuzeonderzoek: Bepaling van de bruikbaarheid van aardappelrassen met resistentie tegen *Globodera pallida* voor de individuele akkerbouwer en het fabrieksaardappelgebied. In: Onderzoek 1990, H.L. Hilbrandslaboratorium voor Bodemziekten, Dekker & Huisman. Wildervank, the Netherlands. p. 120–123.

Nijboer, H. & Parlevliet, J.E., 1990. Pathotype-specificity in potato cyst nematodes, a reconsider ation. Euphytica 49: 39–47.

Phillips, M.S. & Trudgill, D.L., 1983. Variations in the ability of *Globodera pallida* to produce females on potato clones bred from *Solanum vernei* or *S. tuberosum spp. andigena* CPC 2802. Nematologica 29: 217–226.

Seinhorst, J.W. & Oostrom, A., 1984. Comparison of multiplication rates of three pathotypes of potato cyst nematodes on various susceptible and resistant potato cultivars. Mededelingen van de Faculteit Landbouwwetenschappen, Rijksuniversiteit Gent 49: 605–611.

Vanderplank, J.E., 1969. Pathogenic races, host resistance, and an analysis of pathogenicity. Netherlands Journal of Plant Pathology 75: 45–52.