# Resistance and Tolerance to Potato Cyst Nematodes among Ukrainian Potato Cultivars and Breeding Materials

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**Abstract**

Potato is the fourth important cultivated crop in Ukraine; the potato cyst nematode *Globodera rostochiensis*, *Ro1* consists one of the most serious threats to its industry. A total of 3769 cultivars and hybrids were assessed for resistance to *G. rostochiensis* from 1992 to 2002. On the base of the two-stages assay, resistance was identified at 419 and partial resistance at 90 genotypes, which had inherited resistance from 39 resistant cultivars and 23 hybrids. Resistance of the 74 genotypes was confirmed in both greenhouse and field plots; their effectiveness in reduction of population densities of *G. rostochiensis* varied from 51 to 96% in one season. The tolerance of 5 Ukrainian potato resistant cultivars was investigated in the field plots and all of them were classified as intolerant.

**Keywords**: *Globodera rostochiensis*; potato; resistance; tolerance

## INTRODUCTION

Potato is the fourth important crop in Ukraine cultivated in more than 1.5 million hectares, which are approximately 8% of the agricultural land (Figure 1).

In spite of the suitable agronomical conditions for potato-growing industry and high genetic potential of the modern potato cultivars, both production and yield are quite low – 16.980 Mt and 10.8 t/ha respectively (Table 1). One reason is that the 98% of Ukrainian potato industry is based mainly on domestic production in small private land parts and crop is manually managed (Figure 2). Furthermore demand for potato production is influenced by economical pressure associated with changes of political and economical systems. Currently, most of smallholder farmers have low income preventing them from use of the required amount of fertilizer, herbicides and pesticides. As a consequence, plant diseases and pests reduce potato production substantially (KUCHKO & OVERCHUK1994; OVERCHUK 1995).

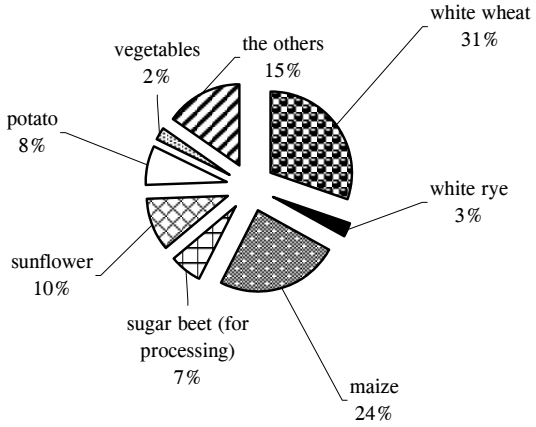


Figure 1. Quota in an area harvested of the main crops in Ukraine (1990–2000) (data from Ministry of Agricultural Policy of Ukraine, Agricultural Production Statistics Database)

One of the most serious pests of potato in Ukraine is the potato cyst nematodes *Globodera rostochiensis* (Wollenweber, 1923; Behrens 1975), pathotype *Ro 1* (SIGAREVA et al. 1998) which was first recorded in 1963 (NIKITIN 1972). It is assumed that potato cyst nematode introduced with the imported potato seed material from neighboring European countries. Since then, *G. rostochiensis* has been spread in 12 out of 25 regions of the country and, in accordance with the data of General State Inspection on Quarantine of Plant, now is common in an area of about 6000 ha (PYLYPENKO 1998a). However that is based on a


Figure 2. Quote of domestic production in potato industry of Ukraine (data from Ministry of Agricultural Policy of Ukraine, Agricultural Production Statistics Database)

limited number of inspections due to the restricted financial support for such monitoring programmes. Furthermore most farmers of small land do not record the problem as their production is designated mainly for their own consumption. Thus, there are several reasons to suppose that the infested area is quite larger. In such circumstances *G. rostochiensis* causes significant yield losses that range from low decrease of yield to total crop destruction (POLOZHENEC 1995; PYLYPENKO 1998b).

Generally, the main measures for controlling the potato cyst nematode are nematicides, crop rotation and resistant/ tolerant cultivars of potato (BRODIE 1984; PHILIPS & TRUDGIL 1998; WHITEHEAD & TURNER 1998). Nematicides are not available in Ukrainian market and crop rotation is not usually a practical control measure because of the intensive land use. Moreover, the increased monoculture, the reduced crop diversity and private seed production increase the problem of the potato cyst nematodes in small land pieces. Consequently the only feasible control method for the pest is growing resistant and tolerant potato cultivars (PYLYPENKO 1998b).

In the 1980's a breeding programme initiated in Ukraine to produce potato nematode resistant cultivars. The study described here conducted to assess the levels of resistance and tolerance to *G. rostochiensis* in the produced potato cultivars and breeding material.

## MATERIALS AND METHODS

Potato cultivars and breeding material were obtained for assessment from 5 different institutions and 4 experimental stations. Assessment of the plant resistance

Table 1. Production of potatoes in Ukraine (data from Ministry of Agricultural Policy of Ukraine, Agricultural Production Statistics Database)

| Year | Area harvested (1000 ha) | Yield (t/ha) | Production (1000 t) |
|---|---|---|---|
| 1991 | 1533.7 | 9.5 | 145 50 |
| 1992 | 1705.3 | 11.9 | 202 77 |
| 1993 | 1534.1 | 13.7 | 210 09 |
| 1994 | 1527.4 | 10.5 | 161 02 |
| 1995 | 1530.6 | 9.6 | 147 29 |
| 1996 | 1548.9 | 11.9 | 184 10 |
| 1997 | 1577.4 | 10.6 | 167 01 |
| 1998 | 1513.2 | 10.2 | 154 05 |
| 1999 | 1551.1 | 8.2 | 127 23 |
| 2000 | 1631.0 | 12.2 | 198 38 |
| 2001 | 1603.5 | 10.6 | 170 33 |
| Mean | 1568.7 | 10.8 | 169 80 |

to the potato cyst nematodes was conducted in three stages. The primary (1st year) assay was done to identify susceptible cultivars and breeding material in the greenhouse plots. Then, only nematode-resistant and partially resistant genotypes were tested in the secondary (2nd year) assay in the greenhouse plots as well as in the primary assay. Genotypes, which had been characterized resistant in both the primary and secondary assays, were tested in the main assay (3rd year) simultaneously in the greenhouse and field plots, in order to confirm their level of nematode resistance and to determine their effectiveness against *G. rostochiensis*.

All experiments in greenhouse plots were carried out under optimal conditions for the growth and development of potato (air temperature 20–22°C, water supply as required). Plastic boxes (500 $cm^3$) were filled with naturally nematode infested soil, the inoculum level was 50 juveniles and eggs (juv + eg) of *G. rostochiensis* per 1 $cm^3$ of soil). Each genotype was planted separately (3 tubers for the primary assay, 5 – for the secondary assay and 10 – for the main assay). The roots of plants were examined 60–65 days after planting, when cysts were well developed. Root balls were removed from the boxes and the number of newly formed cysts, visible on the root ball, was counted. Resistance of tested genotypes was classified in three different categories based on the average number of cysts on roots: 0 – resistant; 1–5 – partially resistant; > 5 – susceptible. Nematode-resistant Vodoghrai and susceptible Svitanok kyivs'kyi, Luhovs'ka cultivars were used as controls.

Trials in the field plots (3rd year) were carried out on a moderate infested soil (50–100 juv+eg/1$cm^3$) in the same field for all cultivars. For the main assay, 120 tubers of each genotype were used. The effectiveness (Ef) of nematode-resistant cultivars against *G. rostochiensis* in the field plots was evaluated by the reduction of the potato cyst nematodes population density after growing nematode-resistant cultivars and hybrids, using the formula:

$$Ef = \frac{(Pi - Pf)}{Pi} \times 100\%$$

where: *Pi* – initial population density of potato cyst nematodes
*Pf* – final population density

Cysts were extracted from soil using the Fenwick's can (FENWICK 1940) and counted using a stereomicroscope after appropriate preparation (KIR'YANOVA & KRAL 1969). The number of juveniles and eggs extracted from cysts from a 1 $cm^3$ soil sample (juv + eg/1$cm^3$) was used as an index of density of the nematodes population.

Tolerance to *G. rostochiensis* of 5 Ukrainian nematode-resistant potato cultivars (Fantaziia, Obrii, Povin', Dniprianka and Slov'ianka) were assessed by recording the tuber yield in a moderate (44–53 juv+eg/1 $cm^3$) and a heavily (132–164 juv+eg/1 $cm^3$) infested field, proportionally to the yield in an uninfested field of the same area. Cultivars were described as tolerant if yield losses were less than 20%. Nematode susceptible potato cultivar Nezabudka was used as a control. The data were subjected to statistical analysis with calculation of the least significant differences ($P \leq 0.05$).

All fields were fertilized as required and fungal diseases and pests were controlled following standard agricultural practices. Tubers were harvested when fully matured.

## RESULTS

### Experiment 1 – Assessing resistance to *G. rostochiensis* within a breeding programme

A total of 3769 potato cultivars and hybrids were assessed for resistance to *G. rostochiensis* from 1992 to 2002 (Figure 3).

In the primary assay, 2984 genotypes were tested; 1526 of them were classified as resistant or partially resistant to *G. rostochiensis* and 1458 characterized susceptible and rejected from the further investigation.

From the 1526 resistant and partially resistant cultivars and hybrids, 705 appeared to be potential for a breeding programme due to desired agronomic characters, and were chosen for the secondary assay. On the base of the two-stages assay, resistance was identified only at 419 cultivars and hybrids and partially resistance at 90 (the remaining 196 genotypes were rejected as susceptible to *G. rostochiensis*). These resistant and partially resistant cultivars and hybrids had inherited resistance from 39 nematode resistant cultivars and 23 hybrids. The sources of resistance more frequently used, were cultivars Gitte (10.9% of combinations), Berehynia (10.5%), Dobrochyn (7.6%), Chernihivs'ka rannia (5.7%), Granola (5.2%), Sante (3.8%), Bilorus'kyi 3 (3.8%), L'viv'ianka (3.3%), Gusto (2–9%), Ceasar (2.4%), Barbara (1.9%); the remaining 28 cultivars had been used in 0.5–1.4% of combinations.

Within 419 nematode resistant cultivars and hybrids, 74 which had several commercially desirable characteristics including marketable yield, good taste and processing qualities, were selected for the third-main-stage of assay. Resistance for all of them

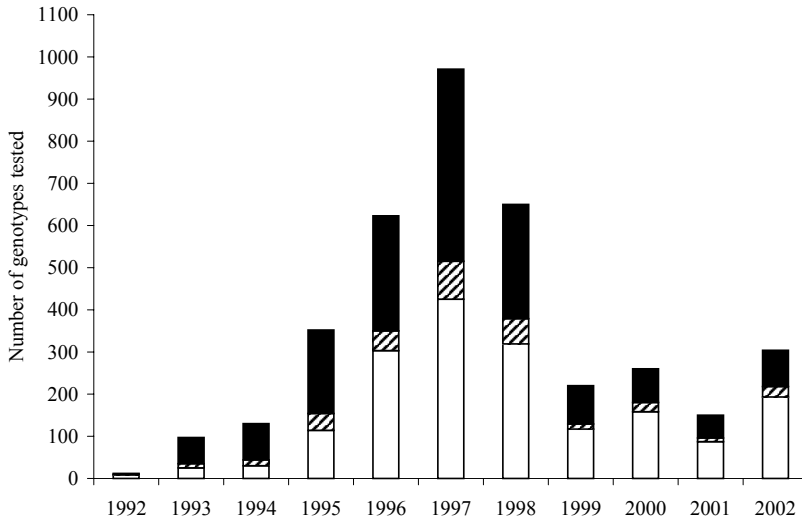


Figure 3. Number of resistant, partially resistant and susceptible to *G. rostochiensis* genotypes, found among Ukrainian potato cultivars and breeding materials (for each year separately)

was confirmed in both greenhouse and field plots. Growing such resistance genotypes in the field plots decreased soil infestation from 51 to 96% in one season. Analysis of variance showed that the effectiveness of nematode resistant cultivars against *G. rostochiensis* varied according to the local weather conditions, soil type, initial densities of the nematode, length of plant vegetation and fertilizer inputs.

### Experiment 2 – Evaluation of tolerance to *G. rostochiensis* of nematode resistant cultivars

The tolerance of 5 Ukrainian resistant potato cultivars was investigated in the field plots naturally infested with a range of nematode densities. Significant differences ($P \leq 0.05$) in yield reduction between cultivars were observed. Reductions of 28–38% were recorded at moderate infestation levels and 40–59% at heavy infestations (Table 2). Such results indicated that the resistant cultivars tested (Fantaziia, Obrii, Povin', Dniprianka and Slov'ianka) are intolerant. However, it is important to indicate, that in spite of such significant yield losses of all nematode resistant cultivars, losses of susceptible cultivar Nezabudka (control) were significantly higher: 56% at moderate and 76% at high population densities ($P \leq 0.05$).

## DISCUSSION

Ukrainian breeders have been breeding potatoes for nematode resistance since the 1980's. The first resistant cultivar released in Ukraine was Prolisok (1991), and up to 1994 there were only three nematode resistant cultivars in National List (Prolisok, Berehynia, Siednievs'ka rannia). Although considerable effort was invested on selection for resistance, it was restricted

able 2. Tuber yields (kg fresh weight per plant) and yield losses in *G. rostochiensis* infested fields for the five nematode resistant cultivars

| Cultivar | Uninfested field ($Pi$ = 0) | Moderate infested field ($Pi$ = 44–53 juv+eg/1 cm$^3$) | Yield losses (%) | Heavily infested field ($Pi$ = 132–164 juv+eg/1 cm$^3$ | Yield losses (%) |
|---|---|---|---|---|---|
| Fantaziia | 819.3 | 566.7 | 31 | 337.5 | 59 |
| Obrii | 578.1 | 359.3 | 38 | 279.5 | 52 |
| Povin' | 588.9 | 431.4 | 27 | 337.5 | 43 |
| Dniprianka | 895.0 | 640.9 | 28 | 431.1 | 52 |
| Slov'ianka | 1059.4 | 722.9 | 32 | 634.9 | 40 |
| Control cv. Nezabudka | 442.4 | 192.8 | 56 | 105 | 76 |

by the limited number of research centres involved in the breeding programme. Moreover, for long time breeding materials had been tested for resistance to *G. rostochiensis* outside of Ukraine – in Belarus. This situation has changed since the early 1990's, when several research institutions were incorporated into an official breeding programme and a new centre for assessing resistance to potato cyst nematodes was established at Department of Nematology at Institute of Plant Protection, Ukrainian Academy of Agrarian Science. Therefore 3769 cultivars and hybrids from 9 research institutions were assessed for resistance to *G. rostochiensis* from 1992 to 2002. After the three-years assessments 18 from 74 Ukrainian nematode resistant potato cultivars with commercially desirable characteristics were officially registered. In our experiments, these cultivars decreased soil infestation from 51 to 96% in one season.

Ideally, nematode resistant potato cultivars should be sufficiently resistant to control nematode infestations and also tolerant to produce an economic yield in infested soil (ARNTZEN 1993; DALE *et al*. 1998). However no information on tolerance of nematode resistant potato cultivars is available in the Ukrainian Cultivar List, although differences in tolerance within the Ukrainian potato cultivars and breeding materials have been observed (PYLYPENKO 1998b).

Different approaches have been suggested for screening potato cultivars for their tolerance to the potato cyst nematode (TRUDGILL 1986; DALE *et al*. 1988; PHILLIPS *et al*. 1988; EVANS & HAYDOCK 1990; ARNTZEN 1993). For most tests two key components are necessary: (i) growing plants in nematode infested and uninfested soil, and (ii) using some standard cultivars as tolerant and intolerant controls. For example, in the UK cultivar Cara has been widely used as tolerant and Pentland Dell as intolerant controls (TRUDGILL *et al*. 1998). The use of three standard cultivars for tolerance assessment has been described by ARNTZEN (1993).

The data presented here show that none of the five nematode resistant cultivars are tolerant to a range of soil infestations. Therefore, there is an urgent necessity to assess tolerance of all Ukrainian nematode resistant cultivars, as well as susceptible ones, in order to find appropriate potato genotypes, which should be used as standards for tolerance screening in a *G. rostochiensis* resistant breeding programme.

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