Resistance of *Rosa* Species and Cultivars to *Pratylenchus penetrans*

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Abstract. Methods to screen for resistance to root-lesion nematode *Pratylenchus penetrans* in *Rosa* were modified to screen-rooted materials. Sixty days after rooting, plants were transplanted into 50-mL pots filled with river sand and each inoculated with 500 *P. penetrans* in 400 µL water 10 days later. The inoculated plants were fertilized weekly and incubated in a growth chamber or a greenhouse for 5 months when nematodes were extracted from the sand and root system and enumerated. When used for screening of the 131 *Rosa* accessions, this approach allowed the observation of a large variation in host suitability. While a majority of the accessions supported the multiplication of *P. penetrans*, previously reported resistance of *R. multiflora* ‘K1’ and *R. virginiana* to *P. penetrans* was confirmed. *Rosa laevigata anemoides* allowed a significantly lower nematode multiplication than the currently prevalent rootstock *R. corymbifera* ‘Laxa’.

The root-lesion nematode, *Pratylenchus penetrans* (Cobb, 1917) Filip’ev & Schuurmans Stekhoven, 1941, is a biotrophic plant parasite on a wide range of hosts mainly in temperate climates. It is one of the principal nematode species infecting ornamental plants. The nematode causes destruction of the root system, which results in loss of vigor in young plants. Serious losses in roses caused by *P. penetrans* were reported in California (Sher, 1959), Canada (Johnson and McClannahan, 1974), Japan (Ohkawa and Saigusa, 1981), and Europe (Coolen and D’Herde, 1970; Coolen and Hendrickx, 1972; Corbett, 1973).

Satisfactory control of *P. penetrans* in the field is achieved by the application of fumigant or non-fumigant nematicides (Corbett, 1973; Richardson and Grewal, 1993). However, increasing concern about environmental contamination stimulates the use of alternative control strategies that make use of resistance and tolerance of species and cultivars (Dubois et al., 1990; Horst, 1983). Resistance and susceptibility of many *Rosa* spp. have been evaluated (Cook and Evans, 1987). Plants that are resistant (support fewer nematodes) or are tolerant (do not exhibit growth reduction) improve nematode management and crop development. The extractable population density in soil and roots of infected plants at the end of the growing season (Pi) and its ratio (Pf/Pi) to the initial population density (Pi) of nematodes are common measurements for comparison of host suitability of plants (Westcott and Zehr, 1991). Accessions with Pf/Pi ratio less than one are considered resistant in that they do not support nematode reproduction. Measurements of plant growth characters are indicators of tolerance (Cook and Evans, 1987).

Resistance and tolerance to nematodes have been important components in a few rose breeding programs (Dubois et al., 1990; Horst, 1983). *Rosa eglanteria* (syn. *R. rubiginosa*) and *R. chinensis* ‘Major’ were found to be the least suitable *Rosa* hosts of *P. penetrans* (Coolen and Hendrickx, 1972; Ohkawa and Saigusa, 1981). In a previous study, we detected partial resistance to *P. penetrans* in *R. virginiana*, which supported significantly lower multiplication of the nematode than the control *R. corymbifera* ‘Laxa’ (Peng and Moens, 2002a). In the present study, we evaluated the host suitability of 131 accessions of *Rosa* sp. for *P. penetrans*.

Materials and Methods

Inoculum preparation. The population of *P. penetrans* used in this study was isolated in a mist chamber (Seinhorst, 1950) from maize roots collected in a field at Lokeren, Belgium. Traditional species identification using morphology and morphometrics was confirmed with rDNA-RFLP patterns compared to those obtained by Waeyenberge et al. (2000). Isolated nematodes were sterilized with a mixture of malachite green and streptomycin sulfate for 10 min (Peng and Moens, 1999) and were cultured in the sand and root system and enumerated. The adult to juvenile ratio of the inoculum varied between 1 and 1.2. The sequence of extraction, sterilization, and culturing on carrot disks was repeated to build up and to maintain the nematode population. The isolate used in this study was shown to be pathogenic on *Rosa* after its inoculation on seedlings of *Rosa corymbifera* ‘Laxa’ (Peng and Moens, 2002b). Determination of optimum inoculation density. Optimum inoculation density was identified in an experiment conducted in a growth chamber. Fifty-day-old plants of the known susceptible standard *R. corymbifera* ’Laxa’ were transplanted into 50-mL pots filled with sand (sizes between 150–212 µm) and amended with 27.75 mg·mL⁻¹ soluble composed fertilizer M77 (Scotts, The Netherlands) according to Peng and Moens (2002a) and subjected to a 12-h photoperiod and temperature and relative humidity set at 22 °C and 85% during the light and 20 °C and 80% during the dark. Ten days later they were inoculated at their base with 125, 250, 500, or 1000 mobile stages including larvae and adults of *P. penetrans* that had passed through the filter paper placed under the carrot disks in the mist chamber. Nematodes were inoculated in 400 µL water. Plants were placed in a completely randomized design. Each treatment was replicated 8 to 10 times. Each week, every pot was watered (10 mL) twice and fertilized once (10 mL) with 7.5 mg·mL⁻¹ M77 fertilizer. Fifty days after inoculation, *P. penetrans* density was determined separately in the sand and the roots. Roots were cut into 1–2 cm fragments and macerated in 500 mL water in a Waring blender for 90 s. Nematodes were extracted from both the obtained nematode-root suspension or the sand with a fully automated nematode extractor based on centrifugation (Hendrickx, 1995). All the nematodes in the 10 mL extract were counted under a dissecting microscope.

Plant material. A total of 131 accessions of *Rosa* was obtained from different sources (Table 1). The collection was composed of 29 tea or hybrid tea rose cultivars, 11 floribunda roses, 9 hybrid musk roses, 7 shrub roses, 23 other modern roses, 35 accessions of a total of 24 botanical *Rosa* species or subspecies, and 17 other old garden roses. The accessions were classified according to the American Rose Society (ARS) Approved Horticultural Classification (Liberta and Young, 2000). The rootstocks *R. corymbifera* ‘Laxa’ and *R. canina* ‘Pollermiana’ (Pf/Pi = 15.8 and 24.2, respectively) were assigned as standards with known susceptibility.

As seeds were not available for the majority of the screened accessions, each accession was propagated by dipping hardwood cuttings (two leaves) in a mixture of active carbon and 2000 ppm IBA and planted in a shaded greenhouse in a 1:1 sand (v/v) mixture previously pasteurized with steam at 80 °C in late June. Forty days later, the majority of the plants were successfully rooted. After another 20 d, the rooted plants with 3–4 roots and 4–6 new leaves were uprooted. The peat was washed off and plants were transplanted singly into 50-mL plastic pots (see above).

Screening. From Aug. 1998 to Jan. 1999, plants of 59 accessions were screened in a growth chamber (conditions as above). From Aug. 1999 to Jan. 2000, another 72 accessions were screened in the greenhouse (20 to 22 °C) along with ‘Barcarolle’, ‘Pauline Sport’, ‘Pink Prosperity’, ‘Rose Romantic’, and *R. laevigata*

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Table 1. Host reaction of *Rosa* accessions to *Pratylenchus penetrans* 5 months after inoculation with 500 nematodes in 400 µL water in the 1998–2000 screening.

| *Rosa* accessions | Breeder | Group | Source | n | Difference in Pf/Pi Within groups | Maximum Pf/Pi in one of the three replicates |
|-------------------|---------|-------|--------|---|----------------------------------|----------------------------------------|
| Barcarolle | Laperrière, 1959 | HT MR | DPGB | 5 | 1.49 | A | 4.25 |
| Aruba | Spek, 1996 | HT MR | DPGB | 3 | 1.69 | A | 4.04 |
| G.D. Jardins de Bagatelle | de Bagatelle, 1986 | HT MR | DPGB | 3 | 1.89 | A | 5.06 |
| Red Unica | HT MR | DPGB | 3 | 1.95 | A | 3.04 |
| Frederik Chopin | Zyla, 1973 | HT MR | DPGB | 3 | 2.27 | A | 4.04 |
| Pavarotti | deRuiter, 1993 | HT MR | DPGB | 3 | 2.38 | A | 2.76 |
| Dame de Coeur | Lens, 1958 | HT MR | DPGB | 3 | 2.47 | A | 4.78 |
| Paline Sport | RvS-Melle, 1989 | HT MR | DPGB | 7 | 2.49 | A | 7.24 |
| Velvet Fragrance | Fryer’s Nursery Ltd., 1988 | HT MR | DPGB | 3 | 2.97 | A | 4.54 |
| Isabelle | RvS-Melle, 1989 | HT MR | DPGB | 3 | 3.09 | A | 3.96 |
| Christine | McGredy, 1918 | HT MR | DPGB | 3 | 3.66 | A | 5.04 |
| Rossini | HT MR | DPGB | 3 | 3.97 | AB | 6.74 |
| Gypsy Curiosa | HT MR | DPGB | 3 | 4.01 | AB | 5.42 |
| Inka | Tantau, 1978 | HT MR | DPGB | 3 | 4.03 | AB | 6.24 |
| Dream | Dramm, 1938 | HT MR | DPGB | 3 | 4.17 | AB | 8.44 |
| Limona | Kordes, 1993 | HT MR | DPGB | 3 | 5.07 | A | 5.22 |
| Josée | RvS-Melle, 1987 | HT MR | DPGB | 3 | 5.67 | A | 12.78 |
| Orange Unique | HT MR | DPGB | 3 | 5.77 | AB | 7.36 |
| Versa | HT MR | DPGB | 3 | 5.83 | A | 6.50 |
| Texas | Kordes, 1993 | HT MR | DPGB | 3 | 5.91 | A | 6.44 |
| Kiss | HT MR | DPGB | 3 | 5.97 | AB | 11.50 |
| Pascali | Lens, A. Dickson, 1963 | HT MR | DPGB | 3 | 6.11 | AB | 9.36 |
| Auguste Renoir | Meilland, A. A., 1992 | HT MR | DPGB | 3 | 7.38 | A–C | 11.34 |
| Helena | RvS-Melle, 1988 | HT MR | DPGB | 3 | 8.53 | A–C | 12.48 |
| Sweet Shot | HT MR | DPGB | 3 | 8.97 | ABC | 16.12 |
| Madelon | de Ruiter, G., 1987 | HT MR | DPGB | 3 | 13.74 | BC | 17.02 |
| Red Calypso | HT MR | DPGB | 4 | 17.00 | C | 23.88 |
| Katrien | RvS-Melle, 1990 | HT MR | DPGB | 3 | 32.76 | D | 35.56 |
| Ville du Reux | RvS-Melle, 1989 | F MR | DPGB | 5 | 1.64 | A | 3.48 |
| Mercedes | Kordes, R., 1974 | F MR | DPGB | 3 | 2.30 | AB | 5.66 |
| Rose Romantic | Kordes, 1984 | F MR | DPGB | 12 | 2.83 | AB | 8.14 |
| Modern Fire | F MR | DPGB | 3 | 2.99 | AB | 4.02 |
| Floranje | RvS-Melle, 1985 | F MR | DPGB | 4 | 4.30 | AB | 6.84 |
| Miracle | Verbeek, 1962 | F MR | DPGB | 3 | 4.37 | AB | 5.38 |
| Red Velvet | Kordes, 1940 | F MR | DPGB | 3 | 5.85 | AB | 7.50 |
| Gaetane | RvS-Melle, 1985 | F MR | DPGB | 3 | 7.75 | AB | 9.46 |
| Bonica | Meilland, F., 1958 | F MR | DPGB | 3 | 9.81 | A–C | 13.06 |
| Vanille | Kordes, 1994 | F MR | DPGB | 4 | 12.05 | BC | 20.26 |
| Melghory | RvS-Melle, 1982 | F MR | DPGB | 3 | 19.39 | C | 28.24 |
| Pink Prosperity | Bentall, 1931 | HMsk MR | DPGB | 8 | 1.81 | A | 6.01 |
| Lavender Lassie | Kordes, 1960 | HMsk MR | DPGB | 5 | 2.05 | A | 3.93 |
| Felicia | Pemberton, 1928 | HMsk MR | DPGB | 3 | 3.19 | A | 4.52 |
| Plaisanterie | Lens, 1996 | HMsk MR | DPGB | 3 | 3.23 | A | 5.78 |
| Diamond Rose | Lens, 1995 | HMsk MR | DPGB | 3 | 5.97 | A | 9.86 |
| Ravel | Lens, 1987 | HMsk MR | DPGB | 4 | 6.43 | A | 8.70 |
| Jacqueline Humery | Lens, 1995 | HMsk | DPGB | 3 | 6.75 | A | 9.46 |
| Moonlight | Pemberton, 1913 | HMsk MR | DPGB | 3 | 6.82 | A | 7.86 |
| Mozart | P. Lambert, 1937 | HMsk MR | DPGB | 6 | 7.68 | A | 11.52 |
| Camenetta | Central Exp. Farm, 1923 | S MR | DPGB | 3 | 2.16 | A | 2.65 |
| William Shakespeare | Austin, David, 1987 | S MR | DPGB | 3 | 2.31 | A | 2.46 |
| Fredica | INRA, 1974 | S MR | INRA | 3 | 2.59 | A | 4.88 |
| Rush | Lens, 1983 | S MR | DPGB | 3 | 3.97 | A | 5.90 |
| Heidtraum | Noack, W., 1991 | S MR | DPGB | 3 | 5.26 | AB | 7.16 |
| Graham Thomas | Austin, David, 1983 | S MR | DPGB | 6 | 5.39 | AB | 6.92 |
| x 8914 | Lens, 1989 | MR | DPGB | 4 | 1.74 | A | 3.71 |
| Pink Surprise | Lens, 1890 | Min MR | DPGB | 3 | 1.93 | A | 3.46 |
| Flash | Hatton, 1938 | LCI MR | DPGB | 3 | 1.95 | A | 3.28 |
| x 8843 | Lens, 1988 | MR | DPGB | 6 | 2.27 | A | 4.34 |
| Swany | Meilland, Mrs. Marie-Louis, 1978 | Min MR | DPGB | 3 | 2.54 | A | 6.71 |
| Lena | Dickson, R., 1906 | T MR | DPGB | 3 | 2.55 | A | 4.58 |
| Enigma | MR | DPGB | 3 | 3.17 | A | 3.58 |
| New Dawn Somerset | Somerset Rose Nursery, 1930 | LCI MR | DPGB | 3 | 3.20 | A | 6.51 |
| Max Graf | Bowditch, 1919 | HRg MR | DPGB | 3 | 3.67 | A | 12.89 |
| Dr Huey | Thomas, 1914 | LCI MR | INRA | 3 | 3.94 | A | 5.34 |
| Veilchenblau | Schmidt, J.C., 1909 | HMult MR | DPGB | 3 | 4.29 | A | 5.77 |
| Prairie | MR | DPGB | 3 | 4.56 | A | 6.78 |
| Marstem | MR | INRA | 3 | 5.10 | A | 11.60 |
| Kathleen Harrop | Dickson, A., 1919 | B MR | DPGB | 3 | 6.20 | A | 7.96 |

continued on next page.
Table 1. Continued.

| Rosa accessions | Breeder | Group$^a$ | Source$^b$ | n | Difference in Pf/Pi within groups$^a$ | Difference in Pf/Pi between all accessions$^a$ | Maximum Pf/Pi in one of the three replicates |
|----------------|---------|-----------|-----------|---|-------------------------------------|-----------------------------------------------|-----------------------------------------------|
| Excelsa        | Walsh, 1909 | HWiCh | DPGB | 3 | 6.57 A a–c | 9.16 |
| Josephine Charlotte | | MR | DPGB | 3 | 7.23 A a–c | 13.82 |
| Mevr. Nathalie Nypels | Leenders, M., 1919 | Pol. MR | DPGB | 3 | 7.73 A a–c | 13.82 |
| × R. semprevirens | Linnaeus | | | | | |
| Neigé d'été | Gailloux, G., 1984 | Min MR | DPGB | 3 | 11.38 A a–d | 17.94 |
| Romantic Curiosa | | MR | DPGB | 4 | 11.48 A a–d | 15.86 |
| Sander's White Rambler | Sanders and Sons, 1912 | HwHich | DPGB | 9 | 12.69 A a–e | 32.56 |
| Yesterday | Harkness, 1974 | Pol MR | DPGB | 3 | 14.08 A a–e | 25.06 |
| R. indica CE33 | | Sp OGR INRA | 3 | 1.53 A a | 2.50 |
| R. indica CE35 | | Sp OGR INRA | 3 | 2.57 A a | 3.74 |
| R. indica CE4 | | Sp OGR INRA | 5 | 2.60 A a | 4.66 |
| R. indica CE20 | | Sp OGR INRA | 3 | 2.73 A a | 3.08 |
| R. indica CE25-1 | | Sp OGR INRA | 3 | 5.29 A a-c | 7.58 |
| R. indica CE7-1-1 | | Sp OGR INRA | 3 | 5.82 A a-c | 8.56 |
| R. indica 64-11-85-1 | | Sp OGR INRA | 3 | 42.60 A g | 91.60 |
| R. multiflora K1 | | Sp OGR INRA | 5 | 0.88 A a | 2.48 |
| R. multiflora cathayensis | | Sp OGR INRA | 5 | 5.08 A a-c | 7.62 |
| R. multiflora ‘Alfred Dietrich’ | | Sp OGR DPGB | 3 | 8.43 A a-c | 11.99 |
| R. multiflora ‘Catholica angelica’ | | Sp OGR DPGB | 3 | 10.39 A a-c | 10.50 |
| R. multiflora Thunberg | | Sp OGR INRA | 3 | 13.34 A a-c | 17.62 |
| R. multiflora Thuinen | | Sp OGR Lens | 3 | 15.55 A a-c | 30.94 |
| R. glauca Prouet (syn. R. rubrifolia) | | Sp OGR Lens | 3 | 0.75 A a | 1.19 |
| R. californica Chamisso and Schlechtendahl | | Sp OGR Lens | 3 | 1.10 AB a | 1.48 |
| R. holodonta Stark | | Sp OGR INRA | 3 | 3.20 A-C a-c | 3.89 |
| R. glauca Prouet | | Sp OGR Lens | 3 | 3.24 A-C a-c | 4.53 |
| R. hemisphaerica Hermann | | Sp OGR Lens | 3 | 3.37 A-C | 4.49 |
| R. spinissima Linnaeus | | Sp OGR DPGB | 4 | 3.99 A-C | 6.80 |
| R. gallica Linnaeus | | Sp OGR Lens | 3 | 5.21 A-C | 9.07 |
| R. nitida Willnow | | Sp OGR Lens | 6 | 5.86 A-C a | 12.39 |
| R. palustris nutalliana Rehder | | Sp OGR DPGB | 3 | 7.82 A-C | 9.82 |
| R. corymbifera ‘Laxa’ | | Sp OGR Standart | 4 | 15.85 A-C a-c | 22.64 |
| R. virginiana Miller | | Sp OGR Lens | 4 | 16.5 A-C a-f | 32.44 |
| R. hagomins Hemley | | Sp OGR Lens | 3 | 22.83 BC bc | 44.82 |
| R. canina ‘Polmeriana’ | | Sp OGR INRA | 3 | 24.2 C abc | 39.16 |
| R. laevigate anemoides | | OGR | Lens | 5 | 0.56 A a | 0.80 |
| R. johannisens | | OGR INRA | 6 | 1.37 A a | 2.93 |
| R. beggeriana postmarian | | OGR DPGB | 3 | 2.32 A a | 5.65 |
| R. tomentos cinerascens | | OGR DPGB | 3 | 2.44 A ab | 2.55 |
| Jules Margottin | Margottin, 1853 | HP OGR DPGB | 9 | 2.48 A ab | 5.00 |
| R. glauca carmenetta | | OGR DPGB | 3 | 2.87 A a | 3.60 |
| König von Dinemark | Booth, 1826 | A OGR DPGB | 3 | 4.35 A ab | 5.16 |
| R. pendula × R. tomentosa var. ‘Denudata’ | | OGR | Lens | 3 | 5.38 A a-c | 11.22 |
| R. noisettiana ‘Manetti’ | | N OGR INRA | 4 | 6.08 A a-c | 10.22 |
| R. noisettiana ‘Manetti’ CE2 | | N OGR INRA | 3 | 6.39 A a-c | 8.28 |
| R. virginiana × macrophylla | | OGR | Lens | 3 | 6.53 A a-c | 7.79 |
| Rosa × Mariae Graebneriae | Ascheson and Graebner | OGR DPGB | 3 | 7.23 A a-c | 10.55 |
| Coupe d’Hébé | Laflay, M., 1840 | OGR HP DPGB | 3 | 9.26 A a-c | 10.62 |
| R. chinesis Jacquin | | Ch OGR Lens | 3 | 9.56 A a-c | 11.41 |
| Gele Dorenbos | | OGR DPGB | 3 | 10.27 A a-c | 13.21 |
| R. × inulata wilsoni (Borror) Baker | | OGR DPGB | 3 | 31.95 B d–g | 44.96 |
| R. canina ‘Kies’ | | OGR | Lens | 3 | 37.16 B fg | 38.92 |

$^a$Accessions classified according to the American Rose Society (ARS) Approved Horticultural Classification (Liberta and Young, 2000) grouping accessions as Hybrid Tea (HT), Floribunda (F), Hybrid Musk (HMsk), Shrub (S), or other modern roses (MR) including large-flowered climbers (LCI), Hybrid Wichurana (HWich), Bourbon (B), Tea (T), Hybrid Rugosa (HRG), Polyantha (P), Miniature (M), and Hybrid Multiflora (Hmul). Other accessions are botanical species or subspecies (Sp.) or other old garden roses (OGR) including Hybrid Perpetual (HP), Alba (A), China (Ch), and Noisettta (N).

$^b$DPGB: Dept. of Plant Genetics and Breeding, Agricultural Research Centre, Melle, Belgium. INRA: Station de Fréjus, Fréjus, France. Lens: Nurseries Louis Lens, Oudenburg, Belgium. Standaert: Standaert Nurseries, Brugge, Belgium.

$^c$Means of accessions of a same species group followed by a common character are not significantly different according to Tukey honest difference (THD) test for unequal N ($P < 0.05$).

$^d$Means of accessions of a same species group followed by a common character are not significantly different when accessions were compared altogether using THD test for unequal N ($P < 0.05$).
anemonoides, all accessions with a P/Pi<1.0 during the 1998–99 screening, as well as with the randomly selected accession ‘Jules Magrotlin’. In the greenhouse, 4 h of supplemental illumination were applied in winter.

For each accession, three to five plants were screened with 500 mobile stages of *P. penetrans* in 400 µL water (see above). They were placed in a completely randomized design, and fertilized and watered as described above. Five months after their inoculation, nematodes were extracted from the sand and the root system and counted separately (see optimum inoculation density).

The resistance of *R. laevigata anemoides* on which *P. penetrans* did not multiply (P/Pi averaged at 0.80) in the 2 years of screening was confirmed in a 0.5-L pot experiment in 2001. In mid-Sept. 2000, plants of *R. laevigata anemoides* were rooted as above, transplanted into 0.5-L pots filled with sand and inoculated with 500 mobile stages of *P. penetrans* in 400 µL water 10 d after transplanting in early Dec. 2000. Plants of *R. virginiana* and *R. corymbifera* ‘Laxa’ were infested similarly for comparison. Fifty milliliters of 7.5 mg·mL⁻¹ · water (see above) and counted after 20 d postinoculation in rooted sand in the growth chamber.

Statistics. For all of the experiments, P was calculated as the sum of numbers of nematode (including eggs) extracted from both sand and roots. The t and ANOVA analyses were performed with the Statistica software package (StatSoft, 1999). Tukey honest difference test (THD) test for unequal N (Sjøtvoll/Stoline test) was used to compare the means (P = 0.05).

**Results**

**Optimum inoculation density.** Final nematode population on *R. corymbifera* ‘Laxa’ was inoculum density dependent (F = 13.03, P < 0.0001). The differences in P/Pi, however, were nonsignificant between the tested inoculum levels (Table 2). The standard deviation on the P/Pi averages was least at Pi = 500, which was then used during the screening.

**Effects of accession on *P. penetrans* multiplication.** During both screening periods, significant effects of the accessions on the multiplication of *P. penetrans* were observed (F = 4.88, P < 0.0001; and F = 3.81, P < 0.0001, during 1998–99 and 1999–2000, respectively). However, significant effects of screening times were observed among these accessions. *Rosa multiflora* ‘K1’ did not allow nematode reproduction (P/Pi = 0.88) whereas on other accessions of this species great reproduction factors were registered (e.g., *R. multiflora* ‘Alfred Dietrich’ and ‘Catholica Angelica’). The majority of the accessions of *R. indica* allowed medium nematode multiplication, the P/Pi observed on *R. indica* 64–11–85–1 was extremely large (42.60). In one of the replicates of this accession, a P/Pi = 91.6 was scored. *Rosa species* and subspecies other than *R. multiflora* and *R. indica*. One accession of *R. glauca* (syn. *R. rubrifolia*) did not support *P. penetrans* reproduction (P/Pi = 0.75). Another accession from the same nursery, however, did not support nematode multiplication (P/Pi = 3.24). Poor multiplication of the nematode was also observed on *R. californica, R. sempervirens, R. serigeramontosa*, and *P. pendulina pyrenaica* (P/Pi = 1.10–2.09) and good multiplication was observed on *R. canina* ‘Pollimeriana’. The reproduction factor on *R. virginiana* did not differ from the P/Pi obtained on *R. corymbifera* ‘Laxa’ and *R. canina* ‘Pollimeriana’. The maximum P/Pi in these accessions varied between 1.19 and 44.82.

**Old garden roses.** Nematode multiplication on Old garden roses varied in two categories. *Pratylenchus penetrans* did not multiply in any of the five replicates of *R. laevigata anemoides* (average P/Pi = 0.56) whereas very high nematode multiplication was observed on *R. sinuolata willsonii* (P/Pi = 31.95 and R. canina ‘Kiese’ (P/Pi = 37.16). Other accessions supported the multiplication of nematodes, which was not different from that on *R. laevigata anemoides*.

In the experiment comparing the host suitability of *R. laevigata anemoides, R. corymbifera* ‘Laxa’, and *R. virginiana* in 0.5-L pots, the difference in multiplication of *P. penetrans* was significant (F = 45.35, P < 0.0001). The P/Pi on *R. laevigata anemoides* averaged 1.89 and was lower than that of *R. corymbifera* ‘Laxa’ but similar to that of *R. virginiana* (Table 3).

**Discussion**

Because cultural conditions can greatly influence the growth of plants on one hand and the survival, development and reproduction of nematodes on the other hand, it is necessary to conduct resistance-screening experiments in carefully defined conditions. In previous research we determined optimal conditions for screening the host suitability of seed propagated *Rosa* species and cultivars to *P. penetrans*.
Inoculum density was modified here because the amount of the inoculum is critical for differentiating the plant response among genotypes (Fassuliotis, 1985). The inoculum should be enough to establish a population (Kaplan, 1990) and be limited so that high dosages do not cause too much injury and mask potentially useful genetic material (Young, 1998). As the data obtained in the inoculum density experiment did not show differences in multiplication factor between densities ranging from 250 to 1000 and as the standard deviation was least at density Pi = 500, this latter quantity was selected for use in the screening tests.

It is accepted that experiments evaluating plant resistance to parasitic nematodes should have replicates ranging between six and ten because data are often highly variable (Kaplan, 1990). In the reported experiments we frequently observed important variation among replicates. However, less replicates with repeated screening as in reported experiments is acceptable (Kunde et al., 1968). In any case results obtained in pot experiments need to be confirmed in the field. A first selection in a limited number of pots reduces the extent of field experiments.

Nematode reproduction is the selection criterion in resistance screening tests. Reproduction on one accession can be evaluated by comparison with the reproduction on a known resistant accession (Verdejo-Lucas et al., 2000) or by assessing the total number of nematodes extracted from both soil and roots (Potter and Dale, 1994). We used the reproduction factor relating the final population density (found in the sand and the roots) to the inoculum density as suggested by Westcot and Zehr (1991).

When used for the screening of the 131 Rosa accessions, this approach allowed the observation of a large variation in host suitability. Previously reported resistance of _R. multiflora_ ‘Ki’ (Ohkawa and Saigusa, 1981; Santo and Lærd, 1976; Schneider et al., 1995) and one accession of _R. virginiana_ (Peng and Moens, 2002a) to _P. penetrans_ was confirmed in this experiment. However, the resistance of _R. eglanteria_ (Coolen and Hendrickx, 1972) was not confirmed in this and our previous experiment (Peng and Moens, 2002a); the species supported a nematode multiplication similar to that of _R. corymbifera_ ‘Laxa’. _Rosa laevigata_ anemoides was the only species for which resistance was present in all of the tested plants, as none of the replicates scored a PI/Pi>. 1. However, in the 0.5-L pot experiments for which _R. laevigata_ anemoides of another origin was used, the PI/Pi averaged 1.89. Variations between different accessions were also observed in the species of _R. glauca_ and _R. virginiana_. Obviously, the screening of different accessions of the same species is a valuable strategy for searching sources of resistance. The majority of _Rosa_ accessions in our experiment supported the multiplication of _P. penetrans_. It would therefore be of great interest to evaluate the accessions for their tolerance, i.e., the ability to limit the damage caused by nematode infection.

Although screenings using a local pathogenic nematode population are of practical importance for the regional application of resistance or tolerance, results obtained with a single population can not be generalized as differences in pathogenicity were observed among populations of _P. penetrans_ (Peng and Moens, unpublished data) and _P. vulnus_ (Pinochet et al., 1993). Therefore, further screening with populations of various origins would extend the use of resistance in _Rosa_ sp. to _P. penetrans_.

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