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Strawberry Cultivars Vary in their Resistance to Northern Lesion Nematode

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Abstract: The genetic diversity of commercial cultivars of strawberry *Fragaria* × *ananassa* from various parentages, as expressed by their resistance to the northern lesion nematode *Pratylenchus penetrans,* was evaluated in nematode-infested field plots for two growing seasons. Data taken for each plant in each season included soil nematode Pi and Pf, end-of-season nematode numbers in each entire root system, and end-of-season fresh and dry top weight and whole root system weight. Resistance was estimated using an index of the nematode load on the plant:

$$\text{nematode load} = \frac{\text{n(root)} + (200 \times \text{n[soil]})}{\text{root dry weight}}$$

where n (root) = number of nematodes in the root, n[soil] = number of nematodes in 50 g of nonfumigated soil, and 200 is a multiplier to convert the soil nematode count to a 10-kg basis. Nineteen strawberry cultivars varied in their resistance to the northern lesion nematode, from a mean load of 382 nematodes/plant for Pajaro to 1,818 nematodes/plant for Veestar. This variability could be related to the original family groupings, with the most resistant cultivars related to Lassen and the least resistant to Sparkle × Valentine.
Key words: Fragaria × *ananassa,* nematode, nematode load, northern lesion nematode, *Pratylenchus penetrans,* resistance, strawberry, tolerance.

The northern lesion nematode, *Pratylenchus penetrans* (Cobb) Filipjev & Schuurmans Stekhoven, has been found to infest and be pathogenic on the cultivated strawberry, *Fragaria* × *ananassa* Duch. (Potter and Dale, 1991). Several studies have observed that lesion nematode reproduction varies on different cultivars. In West Virginia, Midway strawberry appeared to be a better host than Surecrop (Adams and Hickman, 1970). In Prince Edward Island, significantly more *Pratylenchus* sp. were found in the cultivar Cavalier than in Veestar, Redcoat, or Vibrant, and Redcoat harbored more than Micmac (Kimpinski, 1985). In the Pacific Northwest, no useful resistance was found in 14 cultivars, although the nematode multiplied more readily on some cultivars than on others. For instance, they were able to reproduce readily on the cultivars Olympus, Shuksan, and Tyee, and less on Rainier (Vrain, 1985).

In Poland, Szczygiel (1981) evaluated 28 strawberry cultivars in pots for *P. penetrans* susceptibility in terms of nematode numbers per gram of root and tolerance on the bases of degree of root necrosis and reduction of plant growth. Also, European and North American cultivars were compared. While no strawberry was completely resistant to *P. penetrans,* Guardian, Redchief, and Senga Sengana supported lower numbers of nematodes, whereas Midway, Vesper, and Grenadier supported large numbers. The latter three cultivars also ranked among the highest in root necrosis, along with Cambridge Favourite, whereas Guardian and Senga Sengana were almost equally low on a root necrosis index. However, Midway and, to a lesser extent, Vesper and Grenadier, did not show reduced growth commensurate with the root necrosis index or large numbers of nematodes. Szczygiel (1981) concluded that both root necrosis and reduced growth should be evaluated to indicate nematode-induced damage to a cultivar.

The strawberry can both resist and tolerate the northern lesion nematode (Potter and Dale, 1994). Here we use the terminology of Boerma and Hussey (1992) to describe resistance and tolerance. Resistance describes the ability of a host to suppress nematode development and reproduction, and tolerance describes the sensitivity of a

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host to parasitism or the amount of damage sustained.

The objectives of this study were to evaluate 19 strawberry cultivars for their resistance and tolerance to *Pratylenchus penetrans* and to devise indices to describe these phenomena.

Materials and Methods

Nineteen cultivars of strawberries were used in this study, many of which were closely related: Annapolis ([Micmac × Raritan] × Earliglow), Bounty, Chandler (complex pedigree including 37.5% Tioga and 25% Sequoia, both of which contain 50% Lassen), Glooscap (Micmac × Bounty), Governor Simcoe (Holiday × Guardian), Guardian, Kent ([Redgauntlet × Tioga] × Raritan), Micmac (Tioga × Guardsman selfed), Midway, Pajaro (complex pedigree including 50% Sequoia and two of the other three grandparents of Chandler), Redcoat (Sparkle × Valentine), Scotland (Guardian × [Veestar × NY844]), Selkirk (Earlibelle × Holiday), Selva (complex pedigree including 25% Tioga and two of the other three grandparents of Chandler and a third backcross from *Fragaria virginiana* Duch.), Settler (Guardian × Holiday), Sparkle, Vantage (Tioga × Veestar), Veestar (Valentine × Sparkle), and Vibrant (Sparkle × Valentine). These cultivars fall into two major family groups: those derived from the cultivar Lassen via Tioga (Annapolis, Chandler, Glooscap, Kent, Micmac, Pajaro, Selva, and Vantage) and those directly related to the cross of Sparkle and Valentine (Redcoat, Sparkle, Veestar, Vibrant, and Vantage). Vantage is related to both groups.

The runner plants for the experiment were grown from runner plants in an insect-proof screenhouse in soil that has been fumigated annually with 770 liters/ha of Vorlex Plus CP (1,3-dichloropropene + methyl isothiocyanate + chloropicrin). The runner plants were grown from first-year runner plants from virus-indexed nuclear stock according to the guidelines of the Ontario Strawberry Superior Stock Program (Vandenberg et al., 1991).

The experimental plants were planted on 21 May 1990 and 22 May 1991 in northern lesion nematode-infested soil (Delhi loamy sand: 84% sand, 11% silt, 5% clay, 1.2% organic matter; pH 6.2) (Pi = 1,510/kg soil [1990]; 1,120/kg soil [1991]) at the Agriculture and Agrifood Canada Research Station, Delhi, Ontario. The experimental design was a split-plot design of 12 replicates with the 19 cultivars and an empty plot as main plots, and with soil fumigation or no fumigation as split plots. The mean Pi and Pf for the empty plots in 1990 and 1991 were: Pi = 1895, Pf = 365, and Pi = 970, Pf = 250, respectively. For each main plot, one sub-plot was fumigated with Telone IIB (1,3-dichloropropene) at 220 liters/ha with a handgun 4 weeks before planting and the second sub-plot was not fumigated.

Each sub-plot contained two plants 0.3 m apart with a blank space between sub-plots. Rows were planted 1.25 m apart. All runners were removed throughout the growing season. Weeds were controlled with preplant-incorporated trifluralin and periodic hand weeding. Soil samples were taken for nematode counts from each sub-plot immediately prior to planting and again when the plants were harvested in the fall.

Whole plants were dug on 2 October 1990 and 3 October 1991, and their total fresh weights were determined. The roots were separated from the top growth, and nematodes were extracted from roots. The dry weights of both the top and the roots after extraction were determined after drying at 72 °C for 2 weeks. The nematodes were extracted from the roots with mist sprays at 5-minute intervals in a mistifier for 2 weeks and from 50 g soil/sub-plot, using the Baermann pan method (Townshend, 1963). The extracted nematodes were counted at ×50 with a stereoscopic microscope.

To estimate resistance of the plant to northern lesion nematode, a nematode load index was developed. Since the nematodes move between the root and the soil, the total number of nematodes supported by a plant is the sum of those in both the root and the soil. We considered that the total root system of the strawberry plant occupies about 10 kg of soil. Therefore,

$$\text{nematode load} = \frac{n(\text{root}) + (200 \times n[\text{soil}])}{\text{root dry weight}} \quad (1)$$

where n(root) = number of nematodes in the root, n[soil] = number of nematodes in 50 g of nonfumigated soil, and 200 is a multiplier to convert the soil nematode count to the 10-kg basis.

Since nematode tolerance is a measure of the damage sustained, we defined tolerance as the reduction in plant top growth of the nonfumigated sub-plots compared to that of the adjacent fumigated sub-plot. This is expressed as the top dry weight of the unfumigated sub-plot as a percentage of the top dry weight of the fumigated sub-plot.

Before analysis, the data were transformed with $\log_{10}(x + 1)$. The nematode load index and percent top dry weight were analyzed by analysis of variance with years being considered as the split in a split plot analysis of variance. The two family groups, Lassen vs. Sparkle × Valentine, were contrasted in the analysis of variance. Means separation was tested with the Waller-Duncan K-ratio T-test.

Results

The cultivars differed significantly ($P < 0.0001$) over the 2 years in their nematode load but not in percent top dry weight. Year × cultivar interactions were not significant in either year. The variability among strawberries for nematode load was consistent over the 2 years (Table 1). Four cultivars–Annapolis, Chandler, Glooscap, and Pajaro–had the lowest loads; they were all related to Lassen. Among the cultivars with high loads were those related to Sparkle × Valentine. These two family groups differed significantly from each other ($P < 0.0001$). Vantage, which is a hybrid from Tioga × Veestar, was intermediate in its nematode load between the two parent groups.

Percent top dry weight did not differ significantly among the cultivars, with Selva the lowest with 88% and Redcoat the highest

TABLE 1. Detransformed mean nematode (*Pratylenchus penetrans*) loads and family groupings of 19 strawberry cultivars over 2 years.

Cultivar	Family group	Nematode load[a] 1990	1991	Mean[b]
Pajaro	Lassen	578	252	382 a
Chandler	Lassen	374	639	489 ab
Annapolis	Lassen	760	364	534 abc
Glooscap	Lassen	725	434	561 abc
Bounty	Other	697	488	588 abcd
Guardian	Other	939	432	651 abcd
Micmac	Lassen	656	773	709 abcd
Gov. Simcoe	Other	874	596	722 abcd
Selkirk	Other	1,063	605	802 abcde
Settler	Other	757	859	804 abcde
Scotland	Other	995	740	858 abcde
Selva	Lassen	1,139	661	950 bcde
Vantage	Lassen/Sparkle	969	974	972 bcde
Midway	Other	1,028	1,146	1,085 bcde
Redcoat	Sparkle × Valentine	1,452	876	1,128 bcde
Vibrant	Sparkle × Valentine	1,684	863	1,223 bcde
Kent	Lassen	1,168	1,323	1,236 cde
Sparkle	Sparkle × Valentine	1,527	1,241	1,390 de
Veestar	Sparkle × Valentine	1,425	2,370	1,818 e

[a] $\text{Nematode load} = \frac{n(\text{root}) + (200\times n[\text{soil}])}{\text{root dry weight}}$
where n(root) = number of nematodes in the root, n[soil] = number of nematodes in 50 g of nonfumigated soil, and 200 is a multiplier to convert the soil nematode count to a 10-kg basis, considering that the total root system of the strawberry plant occupies about 10 kg of soil.
[b] Means were detransformed from $\log_{10}(x + 1)$ and were separated with the Waller-Duncan K-ratio T-test. Means in columns followed by the same letter do not differ.

with 116%. The mean percent top dry weight was 99% with a CV of 25%.

Discussion

The nematode load index is advantageous in that it takes a holistic approach to the concept of resistance. It can be argued that the appropriate volume of soil used in our calculation was not the most suitable volume. However, the index does overcome the variability found in studies that use nematodes per weight of root, where the relative number of nematodes in the root can vary from plant to plant.

The index of tolerance, percent top dry weight, was unreliable because of the innate variability in plant growth due to varying climate and edaphic conditions. However, with sufficient replication it may provide a suitable indicator of tolerance to *P. penetrans.*

Strawberry cultivars vary in their resistance, as expressed by nematode load, to the northern lesion nematode. However, complete resistance (immunity) was not found in the cultivars used in this study. The degree of resistance found in different strawberries supports that already reported in the literature. Micmac was more resistant than Redcoat (Kimpinski, 1985), and Guardian was somewhat more resistant than Midway (Szczygiel, 1981).

When the relationships among the cultivars are studied, it appears that many of those related to Lassen from California are more resistant than the others. This would suggest that, within the North American breeding programs, the Californian breeders have inadvertently selected for resistance to the northern lesion nematode while the breeders in the northeastern United States have not. This may well be fortuitous as the California cultivars are derived from somewhat different founding clones than the northeastern cultivars (Sjulin and Dale, 1987).

The continuous nature of the variation, together with the relatively distinct family groupings for resistance to the northern lesion nematode, suggests that resistance can be improved by breeding. Potter and Dale (1994) have shown, in a strawberry family based on crosses of the cultivars Midway × Guardian, that offspring can be selected with at least the resistance levels of their parents. Since the California cultivars have been used successfully in breeding programs in other North American production regions (Luby et al., 1991), the genes for resistance to the northern lesion nematode already will have been successfully introduced into other breeding programs. Examples of this introduction are typified by the cultivars Annapolis and Micmac used in this study. It is clear that with careful screening of strawberry cultivars and selection of their offspring, progress can be made toward increased resistance to the northern lesion nematode.

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