PLANT AND SOIL NEMATODES

RESISTANT AND TOLERANT CULTIVARS AND ROOTSOCKS: ONE OF THE MOST SUSTAINABLE OPTIONS FOR REDUCING LOSSES FROM PLANT-PARASITIC NEMATODES

Growing crop cultivars that are resistant to an economically important nematode pest is a widely used nematode management practice in Australia. It is an ideal way of preventing crop losses because 1) there is very little nematode reproduction on a resistant cultivar and so populations are maintained at very low levels; 2) a resistant cultivar does not require special application techniques or have toxic off-target effects, as occurs with nematicides; and 3) there is no additional cost involved in planting a resistant cultivar. In fact, for most low-value crops, growing resistant cultivars is the only practical way of obtaining long-term control of a plant-parasitic nematode. Tolerant cultivars are also useful because they ensure that the crop will yield reasonably well in the presence of high nematode populations.

What is resistance and tolerance?

The term **resistance** describes the effect of the host on nematode reproduction. A **completely resistant** plant allows no reproduction; a **partially resistant** plant supports moderate levels of reproduction; and a **susceptible** plant allows nematodes to multiply freely.

Another important point to recognise is that crops vary in their capacity to withstand the damage caused by nematodes. A **tolerant** crop will suffer little yield loss when grown in fields infested with high numbers of nematodes whereas an **intolerant** crop will yield poorly in such situations.

One important point to note is that resistance and tolerance are quite different. Resistance describes the effect of the host on nematode reproduction whereas the term tolerance should be restricted to describing the amount of host injury. Thus, resistance and tolerance are independent concepts. When nematode reproduction and crop performance are being evaluated on various crops or cultivars, it is important to recognise that different scenarios may eventuate (Table 1).

Table 1. Possible combinations of resistance, susceptibility, tolerance, and intolerance in a crop genotype with respect to nematode reproduction and plant response to nematode parasitism (From Trudgill 1991)

	Host growth	
Nematode reproduction	Good	Poor
Good	Tolerant/susceptible	Intolerant/susceptible
Poor	Tolerant/resistant	Intolerant/resistant

Comments on the above scenarios are given below.

- An intolerant/susceptible crop is the worst-case scenario, as the crop is a good host and is badly damaged by the nematode. In some cases, the roots of a crop may be so badly damaged that the nematode multiplication rate is reduced. Although such crops may appear to be resistant, they should be classified as intolerant/susceptible
- If a plant performs poorly in the presence of nematodes it is intolerant. However, if the nematodes fail to multiply on the plant, it would be classified as intolerant/resistant. Although such a plant does not produce a high yield, it may be useful in a resistance-breeding program
- A crop or cultivar that allows nematode reproduction but suffers little yield loss (i.e. it is tolerant/susceptible) may be useful in some situations. Despite the fact that it will increase the nematode population, it could possibly be grown in fields where the nematode population is high
- A plant that is tolerant/resistant is the ideal scenario, as it suffers little damage from the nematode, and also limits reproduction

Resistance mechanisms

Most studies on resistance mechanisms have been done with sedentary endoparasites such as the root-knot and cyst nematodes. This group of nematodes modify the root cells on which they feed. Resistant plants often react to their presence by producing a hypersensitive response where these cells turn brown and die.

In other cases, phytoalexins are produced that inhibit nematode reproduction. For migratory endoparasites, resistant plants may have thickened root tissues that are a barrier to penetration or may produce toxins which inhibit nematode activity.

Breeding for resistance and tolerance

When a breeding program for resistance or tolerance to nematodes is being set up, the essential starting point is to assay seed stock and existing cultivars of the target crop and find the desired trait. Although huge numbers of plants must be assessed, screening for resistance is relatively simple. A pure culture of the nematode is established, plant populations are screened in the greenhouse, and the nematode multiplication rate is assessed by measuring initial and final nematode population densities. Assays may also be done in field plots using naturally infested soil. Screening for tolerance is much more difficult because field trials involving large numbers of plants must be established and data on growth and yield must be collected.

Once nematode-resistant or tolerant plants are identified, the approach used to develop commercially acceptable cultivars with resistance or tolerance will depend on the reproductive biology of the crop; whether the resistance is found within the crop species or in a closely related species; and many other factors. Examples of the breeding strategies that have been used for some economically important nematodes are given by Cook and Evans (1987) and Starr and Mercer (2009).

Challenges with using resistance and tolerance as management tools

Resistance is not a universal solution to nematode problems because it is only effective against a single species, or in some cases only one race or biotype of a single species. Thus, a resistant cultivar or rootstock will not control the range of nematode pests that collectively cause damage to some crops. Another drawback is that, as shown in the examples below, the repeated use of single resistance genes often causes changes in the virulence characteristics of the nematode population, and so the specific resistance gene is no longer effective.

- Soybean cultivars with limited sources of resistance to soybean cyst nematode (*Heterodera glycines*) have been used intensively in the USA for many years, but genetic selection for virulence has meant that the nematode is still causing major crop losses in mid-western regions
- In California, tomato cultivars with the Mi-1 gene provide resistance to root-knot nematodes (*Meloidogyne incognita* and *M. javanica*). However, because resistance was the only control tactic used in the processing tomato industry, resistance-breaking biotypes appeared after about 25 years and so resistance was no longer effective

Although lack of durability has been a problem with some resistance genes, there are situations where resistance has remained effective for many years. Nemaguard, a root-knot nematode resistant rootstock for *Prunus* spp., and Trifoliate orange, a citrus nematode resistant rootstock for citrus, are two such examples. Nematode resistance has also proved to be a useful nematode control tactic in Australia and some examples can be found in Fact sheet PSN 030 (Cereal cyst nematode on cereals), PSN 033 (Root-lesion nematode on cereals) and PSN 048 (Root-knot nematode on grapevines).

References and further reading

Cook R, Evans K (1987) Resistance and tolerance. In Brown RH & Kerry BR (eds.) Principles and practice of nematode control in crops. Academic Press, Sydney, Chapter 6, 179-231

Starr JL, Mercer CF (2009) Development of resistant varieties. In Perry RN, Moens M, Starr JL (eds.) Root-knot nematodes. CAB International, Wallingford, Chapter 14, 326-337.

Sikora RA, Roberts PA (2018) An overview of integrated nematode management technologies. In Sikora et al. (eds.) Plant parasitic nematodes in subtropical and tropical agriculture. CABI, Chapter 23.

Trudgill DL (1991) Resistance and tolerance of plant parasitic nematodes in plants. *Annual Review of Phytopathology* 29, 167-192.

Author: Graham R Stirling, Plant and Soil Nematodes. **Contact details:** graham.stirling@biolcrop.com.au