PHOTO

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Breeding and Selection for Resistance to Root-knot and Lesion Nematodes in *Prunus* Rootstocks Adapted to Mediterranean Conditions

Root-knot (*Meloidogyne* spp.) and lesion (*Pratylenchus* spp.) nematodes attack stone fruit crops in southern Europe (14), causing the destruction of the plant root system, resulting in loss of vigor and yield in young and mature trees (10,11). Breeding for resistance is one of the most neglected approaches for achieving effective control of root-knot and lesion nematodes in fruit tree crops in warm Mediterranean environments, but recently the incorporation of host plant resistance, especially to root-knot nematodes, is being investigated in France, Spain and the United States (3,6,9,11).

There are several aspects to resistance, each of which is important in any rootstock breeding program. These are: achieving a high level of resistance which is *(a)* broad to all forms of the nematode pest, *(b)* stable to factors that may modify resistance expression, and *(c)* durable. The first two concepts could be successfully developed in a *Prunus* breeding and selection program against root-knot nematodes, but the durability of the resistance cannot be guaranteed, since this feature is a function of time and depends on the genetics of resistance involved, on how the trait is transmitted, and on the ability of the nematode pathogen to overcome resistance genes.

The objectives of future rootstock breeding to root-knot nematodes are oriented to incorporate multiple resistance and/or tolerance to other pests and diseases, and abiotic stress factors (drought, iron chlorosis, salinity, and root asphixia) into a new generation of plant material adapted to the production conditions that prevail in the Mediterranean region (5). For example, most of the existing peach rootstocks with a high level of resistance to *Meloidogyne* spp. do not adapt well to growing conditions found in many areas of Spain, southern France, Greece and North Africa. Some tend to suffer badly from iron chlorosis and salinity, and to have variable susceptibility to *Phytophthora* spp. and *Agrobacterium tumefaciens*.

Current efforts have concentrated on selecting *Prunus* rootstocks with a high level of, and broad resistance against root-knot nematodes in peach, peach-almond hybrids and plum (3,4). The selection scheme developed in southern Europe has involved several phases: screening, pathogenicity, and resistance verification, the last one being regarded as very important, as it determines the limits of a specific source of resistance (5). The high intraspecific variability in *Meloidogyne* spp., due to differences in virulence (3), indicates the need for testing plant material against several populations/ isolates of the same and different root-knot nematode species. This will ensure broad resistance, and underscores the importance of maintaining and using a large pathogenic diversity that includes mixtures of isolates for rootstock evaluation (3,4,9). Rootstock selection programs based on one or several nematode isolates are considererd a synonym of wasted effort.

Stress factors, mainly abiotic, may alter the expression of resistance and need to be taken into account during the experimental testing process: high soil temperature and the age of plant material (young) may modify the expression of resistance resulting in a partial loss of resistance in peach and peach-almond hybrids (Amygdalus) but not in plum (*Prunophora*) rootstocks (2,5,15). Salinity, which is of frequent occurrence in Mediterranean environments, does not appear to influence resistance expression (5). Three distinct sources of resistance have been characterized in Amygdalus (almond and peach), in which that derived from cv. 'Nemaguard' (*Prunus persica x P. davidiana*) offers a broader and higher level than other known sources for peach (4). Even stronger resistance is available in Prunophora (mainly plums and apricots involving many species and interspecific hybrids), which appears to provide immunity to all known species of *Meloidogyne*. This source, found in several species of plum and apricot, is not affected by temperature, age of plant material or inoculum pressure (4,5).

Resistance to root-knot nematodes is easy to transmit by hybridization. Most resistances seem to be determined by one major gene or a few dominant genes (4,7,9). In peach rootstocks the mechanisms of nematode resistance involve a hypersensitive reaction (8). In peach-almond hybrids this reaction is slow forming, the nematode being capable of penetrating the root, and establishing a parasitic life cycle. However, as it feeds, giant cells gradually collapse, and the nematode dies, being unable to complete its life cycle (9). During this process, lasting 20 to 30 days, small or incipient galls can be formed. Less is known of the resistance mechanisms in plum.

In contrast to the success achieved against root-knot nematodes, results obtained so far in incorporating resistance against lesion nematodes has been limited to the research undertaken. The economic importance of this group of nematodes in the development of orchard replant problems has been recognized for over 40 years (10,11). Two species of lesion nematodes, *Pratylenchus penetrans* and *P. vulnus* are regarded as economically important in fruit tree crops. *P. penetrans* is common in temperate climates whereas *P. vulnus* is predominant in the Mediterranean basin (13,14). In stone fruit crops (almond, peach, cherry, apricot and plum), the nematode destroys the cortical parenchyma of the root, causing cavities and lesions, and predisposes the infected tissue to secondary infections caused by fungi and bacteria. These symptoms are non-specific; they can easily be overlooked or mistaken for damage caused by other soil pathogens. Damage can seriously affect the early stages of plant development in a nursery or when rootstocks are transplanted into the field, and tends to become evident after the second growing season (13).

Nematicides and tolerant rootstocks have been the main means for managing lesion nematodes. There has been little research on the breeding for resistance for controlling *P. vulnus* in stone fruit rootstocks adapted to warm Mediterranean environments. Resistance to lesion nematodes has been difficult to detect and it has been difficult to transmit the genes from wild *Prunus* or existing germplasm (mainly obsolete plum rootstocks of American origin) into commercial rootstocks. Sources of resistance have been identified in wild *Prunus* (*P. fremonti* and *P. tomentosa*) (13) but, unfortunately, these sources are useless from the breeding standpoint as they do not graft or cross with existing commercial rootstocks. Recent findings also indicate differences in pathogenicity among populations of *P. vulnus*, a consideration that further complicates the evaluation of plant material in the search for resistance and tolerance (12). Despite all of these constraints, a few commercial rootstocks have been found to be moderately resistant to some *P. vulnus* isolates. Since only moderate sources of resistance have been found to individual isolates, pooling genes from different sources appears to be the only long-term breeding strategy that could be effective. Resistance mechanisms to root-lesion nematodes are unknown.

Future perspectives

Application of nematicides (soil fumigants and non-volatile compounds) is still widespread in nursery soils and in orchards, but their use will decrease due to toxicity risks, water contamination and general environmental concerns. The production and distribution of broad spectrum biocides such as methyl bromide will be banned in the near future. Producers will have to manage nematodes with less effective chemical control agents (pre- and postplant treatments) in stone fruit crops, where plants lack host resistance against migratory endoparasitic nematodes. This drawback is compounded by the high incidence of replanting which is so common in Mediterranean production areas. The use of resistant rootstocks is the most effective and economic alternative for controlling these pests (1). Several rootstock species still lack resistance to both nematode pests, such as commercial almond to *Meloidogyne* spp. or most *Prunus* species to *P. vulnus* (11,13,14); this underlines the importance of exploring new resistance sources that can be detected and transmitted through interspecific crosses to obtain commercial rootstocks. There is a need to increase the testing of plant material to achieve this goal. New inputs through molecular biology, such as marker-assisted selection (4), can aid plant breeders with new tools for accelerating the breeding process for incorporating nematode resistance.

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