NEW AND EMERGING ROOTSTOCKS

The Ernie Christ Memorial Lecture[1]

by
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Introduction

New rootstocks for peaches have been recently introduced into the United States through commercial nurseries. Most all of these rootstocks are complex *Prunus* L. hybrids that are propagated asexually. Past experience with newly introduced *Prunus* rootstocks has shown that extensive testing is critical to avoid potential problems in commercial situations due to non-adaptation of some rootstocks to North American climatic and edaphic conditions. In addition, putative resistance of introduced rootstocks to common soil diseases and other pathogens has not always carried over to orchard sites in the United States. To ensure widespread horticultural testing of new rootstocks, the NC-140 regional research group (www.nc140.org) continues to serve as an unbiased tester in many geographic and production areas of the United States, Canada and Mexico.

Economic viability of a fruit production enterprise is linked directly to orchard productivity and management efficiency. To increase productivity and efficiency requires tree survival, managed vigor, and increased marketable yields over the expected life span of the orchard. The growers' choice of rootstock is often as important if not more so than the scion variety whenever peaches are grown on soils having high bulk density, nematodes, root rot pathogens, or other edaphic or replant problems. If one or more of these conditions are present, tree survival and growth can be improved by selecting the appropriate rootstock for each soil or site situation. Peach production has been limited in the past by the absence of rootstocks that moderate vigor or are tolerant to undesirable soil properties, site characteristics, and soil-borne pathogens. As good orchard sites become scarce and chemical control practices become cost-prohibitive or unavailable, new rootstocks will be needed to overcome many soil and site problems that had been corrected previously by orchard relocation or chemical fumigation.

Many new peach rootstocks have been developed in the past 20 years (Loreti, 1994; Loreti, 1997; Reighard, 2000; Moreno, 2004) since those listed by Layne (1987) and Okie (1987). Moreover, many of these are now available to growers in the U.S. This paper discusses some of the recent rootstock releases and their potential for solving some of the specific soil and site problems that stone fruit growers currently face.

Adaptability to Biotic and Abiotic Soil Factors

Parasitic Nematodes

Many nematodes parasitize peach roots and frequently reduce tree growth and survival. Four types of nematodes are recognized as injurious to peach trees in North America (Nyczepir and Becker, 1998). They are the ring (*Criconemoides xenoplax* Raski [= *Mesocriconema xenoplax* (Raski) Loof & de Grisse]), root-knot (*Meloidogyne incognita (Kofoid & White) Chitwood, M. javanica* (Treub) Chitwood , *M. arenaria* (Neal) Chitwood, and *M. hapla* Chitwood), lesion (*Pratylenchus vulnus Allen & Jensen* and *P. penetrans (Cobb) Chitwood & Oteifa*) and dagger (*Xiphenema americanum Cobb*) nematodes. Rootstocks often are categorized as immune, resistant, tolerant or susceptible to nematodes. For a specific nematode species, rootstocks labeled as immune or resistant are poor or non-hosts for nematode survival and reproduction and are not impacted by nematode feeding. Tolerant rootstocks are fair to good

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hosts for a specific nematode, but nematode reproduction and feeding does not significantly alter the rootstock's ability to supply the scion's mineral, hormonal and water requirements to survive, grow and bear fruit. Rootstocks susceptible to a specific nematode are good hosts for nematode reproduction and are impacted negatively by nematode feeding in areas such as tree survival, growth and fruiting.

Ring nematode has been linked directly to the onset of peach tree short life (PTSL) syndrome in the Southeast (Nyczepir et al., 1983**)**. Most new rootstocks have not been tested for reaction to ring nematode. However, older (1980s) rootstock introductions such as the French peach seedling rootstocks Montclar, Rubira, GF 305, and Higama, and the plum hybrids Ishtara and Myran, were good hosts for ring nematode (Westcott et al., 1994) and were susceptible to PTSL (Reighard, unpublished data). In addition, commercial rootstocks such as Lovell, Halford, Bailey and Nemaguard are also moderately to highly susceptible. Thus far, no rootstock has survived better in field tests in South Carolina and Georgia than the regionally developed Guardian® 'BY520-9' (Okie et al., 1994; Reighard et al., 1997). In California, Viking rootstock has shown good tolerance to ring nematode and bacterial canker in unpublished field trials.

Root-knot nematodes cause serious growth reduction in peach trees grown in warmer regions. There are at least five species of root-knot nematode (*Meloidogyne arenaria, M. incognita, M. javanica, M. floridensis, M. hapla*) as well as a number of races within each species that feed on stone fruits. *M.incognita* and *M. javanica* are the most common in the southern United States, whereas *M. hapla* is found in northern areas. Many peach (*P. persica*) rootstocks were introduced for root-knot nematode resistance in the United States in the 20th century (Day, 1953). These included Shalil, Yunnan, Okinawa, and later Higama. All of these rootstocks either were not resistant to *M. javanica* or had other problems and eventually were replaced by domestically developed rootstocks such as Nemaguard, Nemared, Flordaguard, and Guardian®. Hybrid rootstocks such as Atlas and Viking from Zaiger's Genetics are also reported to be root-knot resistant.

Recent introductions having root-knot resistance include peach hybrids Barrier 1 and Cadaman® (both *P. persica* x *P. davidiana*), Penta (Empyrean® 2) and Tetra (Empyrean® 3) (both *P. domestica*), Adesoto 101 (*P. insititia*), plum hybrids Myran (*P. cerasifera* x *P. salicina*), Ishtara (*P. cerasifera* x (*P. persica* x *P. cerasifera*)), Julior (*P. insititia* x *P. domestica*), Hiawatha (*P. besseyi x P. salicina*), peach-almond (*P. dulcis* x *P. persica*) hybrids Garnem (GxN15) and Felinem (GxN22), and Pumiselect® (*P. pumila*) (Esmenjaud et al., 1997; Fernandez et al., 1994; Pinochet et al., 2002; A. Nicotra and Moser, 1997). Most of these rootstocks are adequately compatible with peach.

Root lesion (*Pratylenchus vulnus* and *P. penetrans*) and dagger (*Xiphenema americanum*) nematodes are two other problem nematodes in the northern and mid-Atlantic U.S. peach production areas. Lesion nematodes can significantly reduce tree growth and fruit production if not controlled. *P. vulnus* is a problem in the southern United States and California, while *P. penetrans* occurs in northern areas. Rubira, GF 305, Penta and Tetra are listed as having tolerance to *P. vulnus* in Europe (Alcaniz et al., 1996). Pinochet also reported that Krymsk® 86 has resistance to *P. vulnus* and to a lesser extent 'Krymsk® 1'. However, testing of some of the "tolerant" *P. persica* rootstocks (McFadden-Smith et al. 1998) showed that some were quite susceptible to *P. penetrans* and that the Canadian peach seedling rootstocks Chui Lum Tao and H7338013 were more tolerant in greenhouse studies. Bailey and Guardian® were less susceptible than many of the European rootstocks tested. Thus, multiple nematode species and races create a significant obstacle to finding a broadly adapted, lesion nematode resistant rootstock.

The dagger nematode can be a severe problem in the mid-Atlantic states. The major damage to peach trees from dagger nematode feeding is that it serves as the vector for tomato ringspot virus (*TomRSV*), which causes stem pitting. Since many weed species such as dandelions are hosts for this virus, dagger nematode resistance in rootstocks is the only way to prevent infection. Dagger nematode species are also vectors for nepoviruses in other regions of the world. Peach seedling rootstocks are not resistant to dagger nematodes, and therefore, non-peach rootstocks need to be evaluated for resistance to the nematode or the virus. In contrast, Marianna 2624 (incompatible with peach) was reported in Michigan to have some field resistance (Kommineni et al, 1998). Also, some cherry plum (*P. cerasifera*) genotypes appear to be less sensitive to tomato ringspot virus (Hoy and Mircetich, 1984; Halbrendt et al., 1994). Therefore, rootstocks like Mr.S. 2/5 (*P. cerasifera*), Krymsk® 1, and Krymsk® 2 (*P. incana* x *P. cerasifera*) may offer some tolerance. However, these have not yet been tested in the United States for *TomRSV* resistance.

Soil Texture, pH and Fungal Soil Pathogens

Peach rootstocks are well adapted to sandy, gravelly or loamy soils. Therefore, peach (e.g., Lovell, Nemaguard, Nemared, Bailey, Halford and Guardian®) seedling rootstocks are often the choice for peaches on well-drained, non-calcareous soils.

In contrast, peach seedling rootstocks are generally not adapted to poorly drained, heavy clay soils or to calcareous soils where pH is above 7.5. Poorly drained soils result in tree decline or death. Weak, unproductive, chlorotic trees are typical when grown on peach roots in high pH soils. Alkaline soils are uncommon in North America and are only important in stone fruit production areas in Texas, Colorado, and a few other western locations. Therefore, few rootstocks have been developed for these regions, except for peach x almond rootstocks such as Titan and Hansen 536 and from Zaiger's Genetics, Atlas and Viking, which are interspecific hybrids tolerant of saline and alkaline soils.

Many rootstocks for peach introduced from Europe the past 20 years were developed for calcareous soils. These include Julior, Paramount® (formerly GF 677, a natural peach-almond hybrid), Cadaman®, Barrier 1 (Empyrean® 1 or Primo), Mr.S. 2/5, Adesoto 101 (*P. insititia*), and Garnem, and Felinem (both *P. persica* x *P. dulcis*). Of these new rootstocks, Paramount® grows well on alkaline soils but it is very vigorous and was not as yield efficient as other rootstocks on acid soils (Perry et al., 2000). Adesosto 101 root suckers and may have some incompatibility with peach. Julior, Cadaman®, Mr.S. 2/5 and Adesoto 101 still require more testing with peach in the U.S. based on their recent performance in the NC-140 trials.

On heavy or poorly drained soils, peach seedling rootstocks are at risk of becoming infected with *Phytophthora* or crown rot. Similarly, almost all stone fruit rootstocks are susceptible to the oak root rot fungus (*Armillaria mellea* and *A. tabescens*), regardless of soil texture or drainage. Both of these root rot fungi are difficult to control or eradicate; therefore, genetic resistance to them is highly desirable. *Armillaria* resistance reported for Ishtara and Myran in France has not held up in Georgia and South Carolina field tests. A new (2007) rootstock release, named Sharpe, from USDA-Byron, Georgia is reported to have good tolerance to *Armillaria tabescens*. Therefore, "disease tolerant" rootstocks require regional and local testing to determine their adaptability to each soil type and climate.

Many European rootstocks recently introduced to the United States are listed as tolerant of waterlogging (Moreno, 2004). Rootstocks labeled as tolerant to waterlogged soils include Julior, Penta, Tetra, Mr.S. 2/5, Barrier 1, Adesoto 101, and Krymsk® 1. The season of waterlogging usually is not specified in rootstock release notices, and thus it is not known whether these rootstocks are tolerant to dormant or growing season wet soil conditions. Many of these rootstocks were developed in Mediterranean climates that receive their rainfall in the winter. In North America, waterlogging can occur during the growing season. Viking is listed as tolerant of wet soil conditions, but has not been tested much in the Eastern U.S.

Winter Temperatures

Winter cold hardiness of roots of *Prunus sp.* varies considerably among rootstock cultivars. The absence of snow cover or some orchard floor management practices can increase the susceptibility of stone fruit rootstocks to cold injury. Rootstocks that are inherently cold hardy or de-acclimate at a slower rate after warm temperatures are necessary to grow stone fruit in cold regions. The majority of cold tolerant rootstocks for peaches have originated from the Canadian breeding program (Layne, 1987). Releases of the cold hardy peach seedling rootstocks Siberian C, Harrow Blood, Tzim Pee Tao, and Chui Lum Tao either have not conveyed outstanding cold hardiness to peach cultivars or have had some other deficiency such as susceptibility to ring, root-knot and lesion nematodes or *Armillaria* and *Phytophthora* root rots.

New cold hardy and perennial canker (*Cytospora cincta*) resistant selections from the former Harrow breeding program were tested in a NC-140 peach rootstock test in 20 states and provinces with some success (Reighard et al., 2004). Some of these Harrow selections like H7338013, H7338019, Tzim Pee Tao, and Chui Lum Tao delay scion bloom by 1-2 days in South Carolina. Three Russian rootstocks, Krymsk® 1, Krymsk® 2 (compatibility questions with peach), and Krymsk® 86 may offer more cold hardiness than current commercial rootstocks since they were developed from *Prunus sp*. from regions colder than the stone fruit regions in North America. Another option may be selected clones of *P. americana*, which is a native cold hardy plum. Currently, open-pollinated seedlings from *P. americana* genotypes selected for compatibility with peach are being used as peach rootstocks by several mail order nurseries for the fruit hobbyist market in the northern U.S.

Size Control Characteristics

Tree vigor and anchorage

Peach seedling rootstocks including brachtytic dwarfs rarely reduce scion vigor more than 10-15%. Size control of peaches through rootstocks of other *Prunus sp*. has not been achieved satisfactorily in the past due to incompatibility or poor tree vigor. Without graft compatible and size controlling rootstocks such as in apple, increases in peach orchard productivity via intensive training systems will be difficult to achieve. Therefore, new dwarfing rootstocks for peach must reduce vigor, be graft compatible, and give good fruit production without reduction of fruit size and quality.

Some introduced European and Russian rootstocks reported as semi-dwarfing (approximate percent of peach standard) include Rubira (90%), Tetra (80%), Julior (70%), Mr.S. 2/5 (70%), Adesoto 101 (70%), Pumiselect® (70%) and Krymsk® 1 (60%). In addition, California breeders are developing size-controlling rootstocks for peach (DeJong et al., 2004) of which two have been released and others (i.e., HBOK 10 & 32) are in advanced testing. The new releases are Controller 5 (70% of standard) and Controller 9 (90% of standard). Field trial data show that peach on these rootstocks have maintained yield efficiency and fruit size despite significant tree dwarfing. Another older American bred, semi-dwarfing rootstock, Hiawatha (70% of normal tree size), sometimes exhibits delayed incompatibility with peaches. Furthermore, seedling rootstocks from selected *Prunus americana* genotypes are semi-dwarfing and compatible with peach, but have not been widely tested and commercial availability is limited.

The degree of dwarfing of all of the above rootstocks will vary with the variety, climate, soils, and site history. Therefore, without prior geographic testing, it is uncertain how effective these rootstocks will be as size controlling rootstocks in different peach production regions. Furthermore, some dwarfing rootstocks such as Pumiselect® can have anchorage problems.

Future Commercial Outlook

Since the time from initial testing to rootstock commercialization takes many years, expedited virus testing procedures at NRSP5, Prosser, WA and the U.S. Department of Agriculture Animal and Plant Health Inspection Service in Glenn Dale, Maryland have decreased the time to get new *Prunus* germplasm through quarantine for field evaluation. Furthermore, new rootstocks developed in the United States, France, Italy, Spain, Russia and other breeding programs are primarily complex species hybrids that must be propagated vegetatively. These rootstocks are best reproduced via micropropagation from tissue culture explants. Thus, explant culture will likely be the propagation method of choice to mass-produce these unique hybrid rootstocks. Companies such as Agromillora Catalana, S.A. are just beginning this phase of stone fruit rootstock propagation in the United States (California and Oregon).

Other factors still complicating the commercial release of new rootstocks are patent laws and licensing agreements that must be negotiated between government agencies, breeders, nurseries, and grower groups. Despite these obstacles, many new rootstocks are being tested through regional and national trials such as the NC-140 regional project that evaluates new fruit tree rootstocks across North America. This, in conjunction with new screening methods, genomic markers and extensive cooperation among researchers, should decrease the time to evaluate promising rootstock selections so that new releases for peach growers can occur more frequently than they have in the past.

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