Resistance of Apple Rootstocks to Fire Blight Infection Caused by Internal Movement of *Erwinia amylovora* from Scion Infections

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Abstract

Infection of the susceptible rootstock of a grafted apple tree by *Erwinia amylovora* usually results in girdling, and tree death. Rootstocks can become infected by direct infection through wounds, by infection of suckers, and by internal movement of *E. amylovora* cells from scion infections to the rootstock. It was uncertain that inoculation of ungrafted liners of rootstocks could reliably predict their susceptibility as rootstocks of grafted bearing trees. It was determined that inoculation of the blossoms of 3-yr-old trees caused a high frequency of infection of susceptible rootstocks. Therefore this technique was used to determine resistance of 24 rootstocks under orchard conditions. All trees, grafted with 'Royal Gala', developed severe scion infections following inoculation of blossoms on 19 May 1999. Presence of characteristic bacterial ooze was first observed on rootstocks on 16 June 1999. Greatest incidence of tree death occurred on M.26 (60-92% on two clones), and M.9 (83%). No trees on MM.111, Marubakaido, or B.9 died. Geneva™ (G).16 and G.30 had no tree death, and G.11 had 25%. Very few trees of nine other advanced rootstock selections (including CG3041) from the Geneva rootstock breeding program died. In 2000, a severe natural epidemic of fire blight occurred in another duplicate planting of the same rootstocks. The resistance observed agreed closely with that previously seen in the inoculated block. A second set of rootstocks was evaluated in 2002 by blossom inoculation of 3-yr-old trees grafted to 'Royal Gala' and to 'McIntosh'. Trees on M.9 had 83-100% rootstocks infected; M.26, 30%; M.7, 27-43%; MM.106, 40%; B.9, 0%; and P.14, 100%. G.30, G.65, and CG3041 had 0% rootstock infection. The results indicate that although in most cases the selection for fire blight resistance of seedlings in their first year in the greenhouse, and subsequent retesting as potted liners in the greenhouse, as carried out in the Geneva rootstock breeding program, provide a good indication of the resistance of rootstocks of orchard trees, in some instances there appeared to be a clear difference between resistance as a liner and as a grafted rootstock.

INTRODUCTION

Fire blight, caused by *Erwinia amylovora*, is the most important bacterial disease of apple (*Malus* x *domestica*). A single fire blight epidemic in Michigan in 2000 resulted in the death of over 220,000 trees with a total loss of US $42 million. Annual losses to fire blight and cost of control in the U.S. are estimated at over US $100 million (Norelli et al., 2003a). Fire blight infection of susceptible apple rootstocks, such as 'M.9' and 'M.26', frequently results in necrosis of the rootstock crown and tree death. Fire blight infection of the rootstock can occur by several different avenues including infection of rootstock suckers, basipetal internal movement of bacteria through healthy scion tissue, and direct infection of the rootstock crown through breaks or wounds in the bark (Momol et al., 1998; Norelli et al., 2003b). Rootstock infection has been one of the most economically devastating phases of fire blight for apple growers in New York, Ohio and Michigan. A survey conducted in New York during the 1996/1997 growing season identified several commercial orchard blocks with a 10% incidence of rootstock infection (Momol et al., 1999). For trees in their 4th leaf, total economic loss from a 10% tree loss was estimated to

range from $4,000 to $8,500 per ha, depending upon tree density. These high economic losses result from the cost of tree replacement, lost investment in tree maintenance, and reduced productivity of the block for several years until replacement trees mature.

The objective of The USDA/Cornell Apple Rootstock Breeding Program at Geneva, NY is to develop pomologically excellent rootstocks with resistance to biotic and abiotic stresses. Resistance to *E. amylovora* has been a major objective in the selection of these rootstocks. Although resistant rootstocks do not prevent fire blight infection of susceptible scion cultivars, they do prevent tree loss due to rootstock infection. Progenies of controlled crosses were selected for fire blight resistance following direct inoculation of seedling shoots with *E. amylovora*. The rootstocks 'Geneva™ (G.) 11', 'G.30', and 'G.16' have been released for commercial use. All three rootstocks produce trees that are early bearing and highly productive (equal to 'M.9' in most tests). 'G.16' produces a tree in the 'M.9' size class that is very early bearing. 'G.11' produces a tree in the 'M.26' size class. 'G.30' produces a tree in the 'M.7' size class.

Although the 'Geneva™' rootstocks are known to be resistant to direct inoculation of succulent shoot tips of ungrafted liner plants with *E. amylovora* strains Ea273 or E4001a, it was not known if these apple rootstocks are resistant to infection by *E. amylovora* through other avenues under orchard conditions. The purpose of this study was to evaluate the resistance of the 'Geneva™' rootstocks and advanced selections of the breeding program as rootstocks of grafted trees grown under orchard conditions, and to compare their resistance with that of other apple rootstocks when inoculated with the differentially virulent strain E4001a.

MATERIALS AND METHODS

Rootstocks of grafted fruiting trees were evaluated for their resistance to *E. amylovora* when grown in orchards subjected to blossom blight incited either by controlled blossom inoculation or natural blossom infection. To establish the orchard rootstock liners were planted in a nursery, bud chip grafted with the 'Royal Gala' scion (Summer 1995), grown in the nursery for one season, dug (Fall 1996), graded and stored. Orchards were planted in Spring 1997 at the Research North Farm of the NYS Agricultural Experiment Station, Geneva (inoculated block) and the Smith Farm, Geneva, NY (natural infection) in a randomized block design with 10-24 trees on each rootstock at each site. Trees were grown under recommended commercial orchard practices, trained to a central leader, and provided with post support.

Trees at the Research North Farm all bloomed heavily in 1999 (Fig. 1a) and open blossoms were spray inoculated with the highly virulent *E. amylovora* strain E4001 (originally isolated from pear in Ontario, Canada) using a backpack sprayer (Fig. 1b). To compensate for rootstock effects on the time of bloom and rootstock effects on the number of blossoms on 1-year-old wood, which tend to bloom later, trees were inoculated twice, 12 May 1999 and 17 May 1999, with 1.0×10^7 and 1.4×10^6 CFU/ml, respectively. The inoculum concentration was reduced for the second inoculation date due to the forecast of warmer weather conditions more favorable for blossom blight development (Fig. 1c). Symptoms of rootstock infection (ooze exuding from the rootstocks – Fig. 1d, and blackening of the rootstock) were first seen 4 weeks after infection). Some affected trees died shortly thereafter. In late summer and early autumn, other affected trees developed premature foliar coloration. More dead trees were observed the following year. Final data on trees killed by rootstock infection were taken in October 2000.

During the 2000 growing season an epidemic of rootstock blight resulting from natural blossom infection occurred in the Ray Smith Farm block (Fig. 2). Blocks of 'Jonagold', 'Spartan', and 'Cortland' trees on 'M.9' rootstock adjacent to the trial block sustained 60-80% incidence of rootstock blight. Data on trees killed by rootstock infection were taken in October 2000.

A second group of rootstocks were grafted with 'Royal Gala' or with 'McIntosh', and planted in a block at the Lucey Farm, NYSAES, Geneva, NY in 1999. These trees

were blossom inoculated with *E. amylovora* strain E4001a as described above, in 2002. Final data on rootstock infections and tree death were collected in October 2003.

RESULTS AND DISCUSSION

When grown as rootstocks of fruiting trees in the orchard, 'M.9' and 'M.26' were highly susceptible to rootstock blight with 40% to over 90% of the trees dying within the first year following a fire blight epidemic initiated either by blossom inoculation or natural blossom infection (Table 1). 'B.9', 'G.16', and 'G.30' were resistant to rootstock infection under orchard conditions. 'MM.111' had very few trees with rootstock infection and subsequent tree death. Considering the high resistance of ungrafted, potted liners of 'G.11' to four strains of *E. amylovora* in a greenhouse trial (data not shown), it developed more disease than expected in both orchard trials (ca. 25% of the trees with rootstock infection). However, in comparison to incidence of infection in 'M.9' and 'M.26' clones the level of resistance in 'G.11' should be commercially useful under orchard conditions. Most of the as yet unreleased Cornell Geneva (CG) rootstock selections had high resistance to rootstock infection. The level of rootstock infection and tree death in the naturally infected block validated the results from the inoculated trial, in that natural infection resulted in similar high levels of rootstock infection and tree death to those resulting from inoculation.

The 2002 inoculated trial confirmed the high susceptibility of trees grafted on M.26 and M.9 to rootstock infection. P.14, M.7 and MM.106 also had high rates of infection. B.9 and the released Geneva™ (G.) rootstocks in this trial (G.16, G.30, and G.65) continued to show high resistance to rootstock infection (Table 2).

CONCLUSIONS

The orchard trials and naturally infected block provided dramatic confirmation of the high susceptibility of the popular M.9 and M.26 rootstocks to fire blight infection by internal movement of bacteria from the scion. In general, the Geneva™ rootstocks remained resistant to this type of infection. The dwarfing rootstock, B.9, which had appeared susceptible when inoculated as a potted ungrafted liner in the greenhouse (Norelli et al., 2003), was resistant in the field. Further trials of B.9 and newer rootstocks from the Geneva rootstock breeding programs and other sources are continuing.

ACKNOWLEDGMENTS

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Tables

Table 1. Infection of rootstocks of 3-yr-old 'Royal Gala' apple trees following blossom infection by *Erwinia amylovora*, artificially inoculated in 1999 and naturally infected in 2000.

	Artificially inoculated in 1999		Natural infection in 2000	
Rootstock	No. of trees	% with rootstock infection [z]	No. of trees	% with rootstock infection [z]
M.26 EMLA	12 [y]	83	14 [y]	93
M.26 VF	10	40	14	57
M.9 VF [x]	12	75	11	36
MM.111 EMLA	12	0	13	15
B.9	12	0	14	0
G.11 [w]	12	25	13	23
G.16	16	0	19	0
G.30	18	0	24	4
CG.3041 [v]	12	8	13	0
CG.4202	12	17	27	7
CG.4214	12	0	13	0
CG.5179	12	17	11	0
CG.5757	12	0	13	0

[z] Final determinations of rootstock infection were made in October of the year following infection of the blossoms (ca. 17 months after infection of blossoms)
[y] Percentage of trees with rootstock infection (total number of trees with that rootstock)
[x] Grafted with 'McIntosh'
[w] G. = Geneva™ rootstock (named and released)
[v] CG. = Cornell Geneva selection (not named or released)

Table 2. Infection of rootstocks of 3-yr-old 'Royal Gala' apple trees following artificial inoculation of blossoms with *Erwinia amylovora*, 2002.

Rootstock	Cultivar	No. of trees	% with rootstock infection[z]
M.26	Royal Gala	10[y]	33
M.9	Royal Gala	10	80
M.9	McIntosh	6	83
MM.106	Royal Gala	5	40
M.7	Royal Gala	14	57
M.7	McIntosh	11	27
B.9	McIntosh	11	0
P.14	McIntosh	12	75
G.16 [x]	Royal Gala	11	0
G.30	Royal Gala	5	0
G.30	McIntosh	10	0
G.65	McIntosh	13	0

[z] Final determinations of rootstock infection were made in October 2000 (ca. 17 months after infection of blossoms)
[y] Percentage of trees with rootstock infection (total number of trees with that rootstock)
[x] G. = Geneva™ rootstock (named and released)

Figures

a b c d

Fig. 1. Left to right: a) 3-yr-old apple trees with ‘Royal Gala’ grafted on different rootstocks, b) inoculation with *E. amylovora* E4001a, c) severe infection of blossoms, d) infection of M.9 rootstock with ooze, at Research North Farm, NYSAES, Geneva, NY, 1999.

Fig. 2. Natural infection of 4-yr-old ‘Royal Gala’ apple trees grafted on different rootstocks with fire blight at Smith Farm, Geneva NY, July 2000.