Where Do the Geneva® Apple Rootstocks Fit in New York State?

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This work was funded in part by the New York Apple Research and Development Program, and the NY Apple Research Program.

The Geneva® apple rootstock project has released five rootstocks for commercial propagation and sales. Additionally two more rootstocks will be released in December of 2004 and licensed nurseries will begin commercial sales. None of the new rootstocks areperfect; each has strengths and weaknesses. However, all have good fire blight resistance and are very productive. Commercial nurserymen and apple growers must understand their strengths and deficiencies before their adoption.

High-density apple orchards on dwarfing rootstocks have become common in many apple growing regions of the world. This has allowed apple growers to achieve earlier production, higher production and better fruit quality than previously. However, for many apple growers in North America, New Zealand and many locations in Europe, the bacterial disease fire blight is a serious threat to dwarf apple orchards. M.9 and M.26, the most common dwarfing apple rootstocks, are very susceptible to this disease and in some locations this disease limits the planting of dwarfing rootstocks. Outbreaks of the disease in the Eastern US have decimated many dwarf apple orchards. There is a great need to develop new, highly productive apple rootstocks that are resistant to the biotic and climatic stresses common in North America.

Fire blight usually infects the blossoms during bloom and results in diseased branches that die and give the appearance of burned leaves, thus the name fire blight. Research by Dr. Aldwinckle has shown that once inside the tree, the bacteria can travel symptomless down the trunk to the graft union and the rootstock below. With highly susceptible rootstocks like M.9 and M.26 the rootstock cambium, xylem and phloem at the graft union are killed causing the death of the tree (Figure 1). Although fire blight has been a serious problem for many years in North America, losses of whole orchards were not common until dwarfing rootstocks came into use. With seedling rootstocks that were not as susceptible to fire blight as M.9 and M.26, the scion could become infected but the tree usually survived if the infected parts of the scion were pruned away. The use of resistant dwarfing rootstocks will not prevent the scion from becoming infected, however, since the rootstock will survive an infection the tree will usually survive. This allows growers to prune out the infected parts of the scion and regrow the lost canopy quickly, and thus restore full production much more rapidly than replanting an entire infected dwarf orchard.

Cornell University has had an apple rootstock breeding project located at Geneva NY since 1968. The project was led by Drs. James Cummins and Herb Aldwinckle until Dr. Cummins' retirement in 1993. In 1998 the USDA's Agricultural Research Service joined the

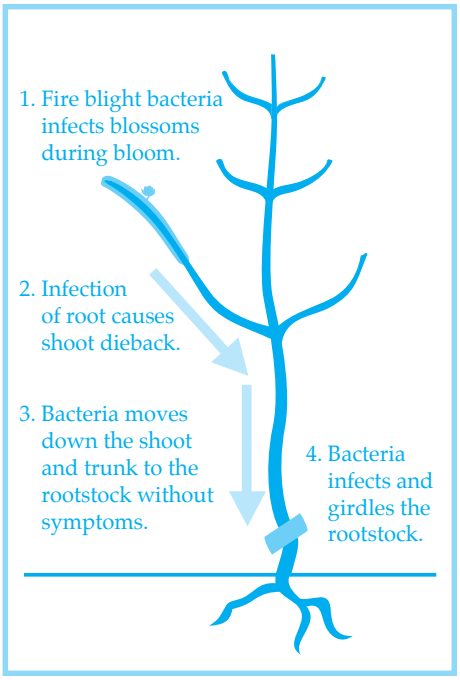

Figure 1. Four steps of fire blight infection of the scion which leads to infection of a susceptible rootstock and tree death.

project along with a new lead scientist (Dr. Gennaro Fazio). The project continues to be joint program between the USDA and Cornell University with Drs. Robinson and Aldwinckle continuing to contribute significant efforts to the program. The objectives of the project are to develop rootstocks with improved nursery and orchard characteristics that are better adapted to the problems of fire blight (*Erwinia amylovora*), crown rot (*Phytophthora spp.*) and replant disease which are common in the USA (Cummins and Aldwinckle, 1983). Additionally, some selections from this project show resistance to woolly apple aphid which is a problem in the warmer apple growing areas of the world. By the early 1990's, Dr. Cummins had selected several promising fire blight-resistant apple rootstocks with a wide range of dwarfing. These were then tested in second level orchard trials that included on-farm trials within New York State (Robinson and Hoying, 2003) and national trials in the USA, and Canada (Robinson et. al., 2003), France (Masseron and Simard, 2002) and New Zealand (personal communication from Stuart Tustin). In this paper, we discuss the combined results from these trials and where these stocks fit in the New York apple industry.

TABLE 1

Ten year performance of G.65 in two trials in NY state.

Trial	Rootstock	TCA (% of M.9)	Yield Efficiency (% of M.9)	Fruit Size (% of M.9)
1991 Empire	G.65	58*	111 NS	—-
1992 Liberty	G.65	58*	97 NS	91*

*Significantly different than M.9 or NS=Not significantly different than M.9 ($p<0.05$).

TABLE 2

Performance of G.16 in three trials in NY state.

Trial	Rootstock	TCA (% of M.9)	Yield Efficiency (% of M.9)	Fruit Size (% of M.9)
1998 Jonagold	G.16	91 NS	111 NS	91*
1998 Gala	G.16	113*	111 NS	92*
1999 McIntosh	G.16	113 NS	131 NS	92 NS

*Significantly different than M.9 or NS=Not significantly different than M.9 ($p<0.05$).

TABLE 3

Performance of G.41 in four trials in NY state.

Trial	Rootstock	TCA (% of M.9)	Yield Efficiency (% of M.9)	Fruit Size (% of M.9)
1991 Empire	G.41	99 NS	123 NS	—-
1993 Liberty	G.41	90*	125*	—-
1998 Jonagold	G.41	96 NS	155*	93*
1999 McIntosh	G.41	126 NS	124 NS	105 NS

*Significantly different than M.9 or NS=Not significantly different than M.9 ($p<0.05$).

CG Rootstocks

To date five rootstocks from this project have been patented and released for commercial propagation and sale by licensed nurseries. Additionally two more rootstocks are being released in December of 2004, and licensed nurseries will be authorized to begin commercial sales.

• **Geneva®65** The most dwarfing CG rootstocks is G.65. It is significantly more dwarfing than M.9 (about 60% the size of M.9) and is similar in vigor as M.27 (Table 1). It is a cross of 'M.27' X 'Beauty Crab'. It has proven to be highly resistant to fire blight and *Phytophthora*, but is not resistant to woolly apple aphid. It has very high yield efficiency but fruit size from trees on G.65 has been only about 90 percent that of trees on M.9 (Table 1). G.65 is somewhat difficult to propagate in stoolbeds which has limited its commercial production but it is available from several nurseries in the USA in limited amounts. G.65 may be too dwarfing for most situations but we believe it has a place in very high planting densities (Super Spindle) with large- fruited varieties such as Jonagold and Mutsu. With these two varieties and other similar large-fruited varieties, fruit size is often too large for optimum commercial packouts. G.65 used as a rootstock would help hold down fruit size. Under these conditions, G.65 has a significant advantage over M.27 due to its fire blight resistance. Orchards with this rootstock should be planted at very high densities of 4,000-6,000 trees/ha.

• **Geneva®16** G.16 is a fully dwarfing rootstock with tree growth and vigor similar to the vigorous clones of M.9 (i.e. Nic29 or Pajam2). It is a cross of 'Ottawa 3' X *Malus floribunda*, is essentially immune to fire blight and highly tolerant to *Phytophthora*, but it is not resistant to woolly apple aphid. G.16 has excellent performance in the stoolbed and produces a large tree in the nursery. Tree growth in the first two years in the orchard is vigorous, but with the onset of cropping, tree vigor is moderated resulting in a final tree similar in size to M.9. Precocity and cumulative yield efficiency have been similar or slightly better than M.9 (Table 2). G.16 appears to have wide soil adaptability and some tolerance to replant disease. It has very good mid-winter hardiness and survived a recent winter freeze event in Northern NY that killed many M.9, M.26, M7 and MM.111 trees. However, it does appear to have some susceptibility to very early winter freeze events. This is likely due to its vigorous growth characteristics in the nursery and in the orchard during the first few years. Its greatest known deficiency it that it is sensitive to one or more latent viruses in scion wood. Infected scion wood results in death of the trees in the nursery or the first year in the orchard. If virus-free wood is used it appears that G.16 is currently one of the best alternatives to M.9 in high fire blight areas. Most commercial nurseries in the US produce trees on G.16 but some scion varieties are not available on this stock because virus-free scion wood is not available. Orchards with this rootstock should be planted at high densities of 2,000-4,000 trees/ha.

• **Geneva®41** A second fully dwarfing stock with vigor similar to M.9 is G.41 (formerly CG.3041). It is a cross of 'Malling 27' X 'Robusta 5'. It is scheduled for commercial release and propagation in December 2004 and will be named Geneva® 41. It is highly resistant to fire blight and *Phytophthora* but it is not resistant to woolly apple aphids. G.41 is a shy rooter and will require higher planting densities in the stoolbed or tissue culture to improve its rooting. It also produces some side shoots in the stoolbed. In the orchard its precocity and productivity have been exceptional, surpassing

TABLE 4

Ten year performance of G.11 in two trials in NY state.

Trial	Rootstock	TCA (% of M.9)	Yield Efficiency (% of M.9)	Fruit Size (% of M.9)
1992 Liberty	G.11	84 NS	114 NS	103 NS
1993 Liberty	G.11	140*	95 NS	—

*Significantly different than M.9 or NS=Not significantly different than M.9 ($p<0.05$).

TABLE 5

Performance of G.202 in two trials in NY state.

Trial	Rootstock	TCA (% of M.9)	Yield Efficiency (% of M.9)	Fruit Size (% of M.9)
1991 Empire	G.202	153 *	101 NS	—
1998 Gala	G.202	93 NS	86 NS	90*

*Significantly different than M.9 or NS=Not significantly different than M.9 ($p<0.05$).

TABLE 6

Performance of G.935 in two trials in NY state.

Trial	Rootstock	TCA (% of M.9)	Yield Efficiency (% of M.9)	Fruit Size (% of M.9)
1991 Empire	G.935	138*	122 NS	—
1998 Gala	G.935	207*	112*	101 NS

*Significantly different than M.9 or NS=Not significantly different than M.9 ($p<0.05$).

TABLE 7

Performance of G.30 in two trials in NY state.

Trial	Rootstock	TCA (% of M.9)	Yield Efficiency (% of M.9)	Fruit Size (% of M.9)
1991 Empire	G.30	191*	101 NS	—
1992 Liberty	G.30	177*	116 NS	106 NS

*Significantly different than M.9 or NS=Not significantly different than M.9 ($p<0.05$).

M.9 (Table 3). It also has excellent fruit size and induces wide branch angles, and has very good winter hardiness. Although it is similar in tree size and yield efficiency to G.16 and M.9, it does not have the virus sensitivity of G.16. It has similar graft union strength to M.9 and will require trellising or individual tree stakes. G.41 has also been tested in France where it was shown to be smaller in tree size than M.9Pajam2 but more productive while producing similar fruit size as M.9 (Masseron and Simard, 2002). Several commercial nurseries in the USA have limited amounts of G.41 for sale this year. Orchards planted with this rootstock should be planted at densities of 2,000-4,000 trees/ha. It appears that G.41 will become one of the best alternatives to M.9 in high fire blight areas.

• **Geneva®11** G.11 is a dwarf rootstock that produces a tree that is similar in size to M.26. It is a cross of 'Malling 26' X 'Robusta 5'. It has good propagation characteristics in the stoolbed and in the nursery. In the orchard it has higher yield efficiency than M.26 (similar to M.9) and produces fruit size similar to M.26 (Table 4). It has moderately high resistance to fire blight (similar to M.7) and good resistance to'*Phytophthora* root rot, but is not resistant to woolly apple aphid. It has also been tested in France where trees on G.11 were 15 percent smaller than M.9Pajam2 but 14 percent greater productivity and similar fruit size as M.9Pajam2 (Masseron and Simard, 2002). Orchards planted with this rootstock should be planted at densities of 1,500-2,500 trees/ha. Presently G.11 is available only in North America and is just beginning commercial sales. Its fire blight tolerance should make it an excellent replacement for M.26 in fire blight prone areas.

• **Geneva®202** G.202 is a semi dwarfing rootstock that produces a tree slightly larger than M.26. It is a cross of 'Malling 27' X 'Robusta 5'. It is resistant to fire blight and *Phytophthora*, but also has good resistance to woolly apple aphid which is important in many warmer climates where woolly apple aphid is an important rootstock pest. G.202 performs moderately well in the stoolbed and produces good quality nursery trees. G.202 has been tested mostly in New York state and New Zealand. In New York it produces a tree 50 percent larger than M.9 and with slightly lower yield efficiency (Table 5). In New Zealand, it has been found to be much more productive than M.26 and is one of the best stocks available. It appears that G.202 will be a useful alternative to M.26 in climates that have problems with woolly apple aphid. Orchards planted with this rootstock should be planted at densities of 1,500-2,500 trees/ha. It was released for commercial propagation in New Zealand by Cornell University in May 2002 and in the US in 2004. Presently it is only available in New Zealand, but rootstock nurseries in the US are beginning production of this stock.

• **Geneva®5935** A second semi dwarfing stock that produces a tree slightly larger than M.26 is G.5935. It is a cross of 'Ottawa 3' X 'Robusta 5'. It has good propagability in the stoolbed and produces a large tree in the nursery. G.5935 is the most precocious and productive semi dwarf CG rootstock available. It has similar efficiency to M.9 along with excellent fruit size and wide crotch angles. In addition, it is very winter hardy. It is highly resistant to fire blight but it is not resistant to woolly apple aphid. In US trials, it produces a tree about 40-100 percent larger than M.9 but with similar or higher yield efficiency and fruit size as M.9 (Table 6). Orchards planted with this rootstock should be planted at densities of 1,500-2,500 trees/ha. It is scheduled for commercial release and propagation in December 2004 and will be named Geneva® 935. It appears that G.935 will be an excellent replacement for M.26.

• **Geneva®30** G.30 is a very productive semi-dwarf rootstock with large fruit size that has proven to be widely adaptable. It is not only highly resistant to fire blight and *Phytophthora*, but is also resistant to apple replant disease and is very winter hardy. It is a cross of 'Robusta 5' X 'Malling 9'. Although it is highly productive in the orchard it is difficult to manage in the nursery. It produces numerous side shoots (spines) on each shoot in the propagation bed. This requires manual trimming of these shoots either before or after harvest from the stoolbed. The removal of the lateral shoots on the liner also removes essentially all of the lateral buds so that new growth the next year in

the nursery row must depend on the development of adventitious buds. This is a slow process which allows 10-30 percent of the plants to dry out and die before they begin to grow. A solution to this problem is to remove only the side shoots on the lower 25 cm of the liner leaving 5-10 cm at the top of the liner untrimmed with live buds for next year.

During the early years in the orchard, tree growth of G.30 is vigorous and very similar to M.7. However, branch angles have been wider than M.7 and the heavy crops on G.30 starting in year three limit tree growth and vigor in later years so that by year 10 it is usually significantly smaller than M.7 and often closer to the size of M.26. G.30 has a relatively weak graft union when it is young. With Gala, R.I. Greening, Honeycrisp, Jonagold, and JoBurn there have been significant tree losses from breakage at the graft union following strong winds. Work by Johnson and Robinson (unpublished) has shown that the graft union of Gala and G.30 is more brittle than M.26 and the union of Empire and G.30 is more brittle than M.7. This means that although G.30 is a semi dwarf tree, it requires a multi-wire trellis to support the tree. Despite its problems G.30 has found a niche in the apple industry due to its high productivity and wide soil and climate adaptability. Cumulative yield efficiency has been three-five times better than M.7 and is very similar to M.9 (Table 7). In France it has produced a tree slightly larger than M.9Pajam2 but with similar productivity as M.9 (Masseron and Simard, 2004). Orchards planted with this rootstock should be planted at moderate densities of 1,000-1,500 trees/ha, but it will require tree support in all situations.

Summary

Fire blight is an important limiting factor to dwarf apple trees in Eastern North America due to the extreme susceptibility of M.9 and M.26 to this disease. Fire blight-resistant rootstocks have been developed through the rootstock breeding project of Cornell University and the federal USDA-Agricultural Research Service at the Geneva Experiment Station. To date five rootstocks from this project have been patented and released to several licensed nurseries for commercial propagation and sale. Additionally two more rootstocks will be released in December of 2004 and licensed nurseries will be authorized to begin commercial sales. None of the new rootstocks is perfect; each has strengths and weaknesses. All have good fire blight resistance and are quite productive. However, each has deficiencies that must be understood by commercial nurserymen and apple growers before their adoption. Currently we suggest G.30 as an excellent semi-dwarfing stock for spur type varieties, replant sites and for northern climates with short cool growing seasons, however, trees on G.30 must be trellised to prevent graft union breakage. In the near future G.935 may replace G.30 for orchards planted with densities of 1,000-1,500 trees/ha. G.11 and G.202 are possible replacements for M.26 and should be used for dwarf orchards planted at densities from 1,500 to 2,000 trees/ha. G.16 and G.41 are possible replacements for M.9 and should be used for orchards planted at densities from 2,000-4,000 trees/ha. For excessively large fruited varieties planted at very high densities of 4,000-6,000 trees/ha, G.65 is better than M.27.

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