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All About Apple Rootstocks

Rootstocks are a key element of any commercial apple orchard. Today's commercial apple trees are not grown on their own roots (Seedlings), but are propagated on rootstocks that can impart important characteristics to the tree, improving the uniformity, economics and profitability of growing apples. Seedlings have increased genetic variability, therefore decreased orchard uniformity, and produce the largest trees, which is not the goal of current commercial apple orchards. The number of rootstocks available commercially has been steadily increasing since the 1970s due to the presence of active breeding programs all around the world. If you are interested in growing apple trees, you need to know about the varieties of rootstocks on the market. Since there is a not a one-size-fits-all rootstock, it is essential to select the rootstock that best satisfies your needs and that performs best under your soil and environmental conditions. This factsheet summarizes important information about currently-available rootstocks and their characteristics, and is targeted mainly towards commercial apple growers.

What are apple rootstocks? Why are they important?

Scientists develop apple rootstocks by fusing, or "grafting," the roots from one tree (rootstock) to the shoots, or "scion," of another. The grower chooses the roots and the scions in an effort to confer a new benefit to both the tree and the scion. This technique has been used for apples for over 2,000 years. Each rootstock will have a different effect on the fruit cultivar, and these effects also vary based on soil and environmental factors. There is no universal ideal rootstock. Therefore, a grower should choose a rootstock based on the orchard's goals and growing conditions.

Rootstocks can be used to improve a broad range of characteristics, including tree vigor, planting density, tree cold-hardiness, resistance to insects, disease resistance (e.g., fire blight, crown and root roots), soil anchorage,

Figure 1. *Buckeye Gala rootstock trial orchard established in 2019 as part of the NC-140 multistate project. Photo: Dr. Macarena Farcuh, University of Maryland.*

crop load, fruit size, fruit yield, ripening time, harvest maturity, fruit quality, and fruit storability, among others. Particularly regarding vigor, apple rootstocks can drastically affect this trait and impact final tree size. A standard apple tree (Seedling) has a height of 30-40 feet. Rootstocks that reduce final tree size by less than 15% of the Seedling are considered "standard;" 25 to 50% are classified as "semi-dwarf;" and those that reduce the final tree size by 55 to 85% of the Seedling are considered "dwarf." Dwarfing trees, achieved by grafting the desired cultivar on to dwarf rootstocks, are planted at higher densities and are more precocious reaching their maximum yield potential in a shorter period of time compared with non-dwarfing trees, making them more desirable for commercial plantings because they lead to higher productivity per acre and earlier return on investment.

In the late 1970s, the NC-140 Multistate Research Project funded by USDA/ARS, began with the aim of evaluating the capabilities and limitations of new rootstocks established under different environmental conditions through North America. Over the years, the membership has grown to include about 22 states, four Canadian

provinces and one Mexican state. The nature of the research now includes evaluation of rootstocks for five tree fruit species, orchard systems, tree fruit nutrition, replant problems, organic apple production, and nursery production techniques for fruit tree propagation. In 2019, the Farcuh Lab at the University of Maryland became one of the collaborators participating in this national effort (Fig. 1). The Project's vital research and evaluations enable growers to choose the best rootstocks for their growing conditions and other needs. Listed below are various commercially important rootstock series with brief descriptions in each case.

Description of existing Rootstock Series

In this section, we describe a variety of characteristics of rootstocks that are commercially-available to growers in the U.S. We examined the following:

- Malling series
- Malling-Merton series
- Budagovsky series
- Geneva series
- Vineland series
- P series
- Supporter series
- Interstems
- Seedling rootstocks (Fig. 2).

Malling Series

The East Malling Research Station in England created the first official rootstock series, starting in 1912. This series is known for size control, early ripening, and high yield. Some of the rootstocks included in this series encompass (in order from smallest to largest): Malling 27 (M.27), Malling 9 (M.9), Malling 26 (M.26), Malling 7 (M.7), and Malling 2 (M.2).

M.27 is a very dwarfing rootstock known for its early ripening time and for being very productive in a vertical axis system. However, the extremely small tree size may be too small for some commercial growers, and the trees require permanent support. This rootstock is mostly used as an intermediate stem piece or interstem on other rootstock series such as the Malling-Merton series (i.e., MM.106 or MM.111). Interstems are described below.

M.9 is one of the most popular dwarfing rootstocks in the U.S. and Europe and is considered a reference in rootstock trials. The advantage of M.9 is its high yield efficiency. This rootstock performs better in a well-drained site and always requires a leader support. As a limitation, it is highly susceptible to fire blight and can develop burr knots. Several M.9 clones that are free of the tomato ring spot virus and apple stem grooving virus confer more benefits, such as M.9 NAKB 337 and M.9EMLA. In general, virus-free rootstocks are slightly more vigorous than the original that contains viruses.

M.26 is a dwarfing or semi-dwarfing rootstock (variable based on soil type, scion cultivar and production system) that is also among the most popular in commercial

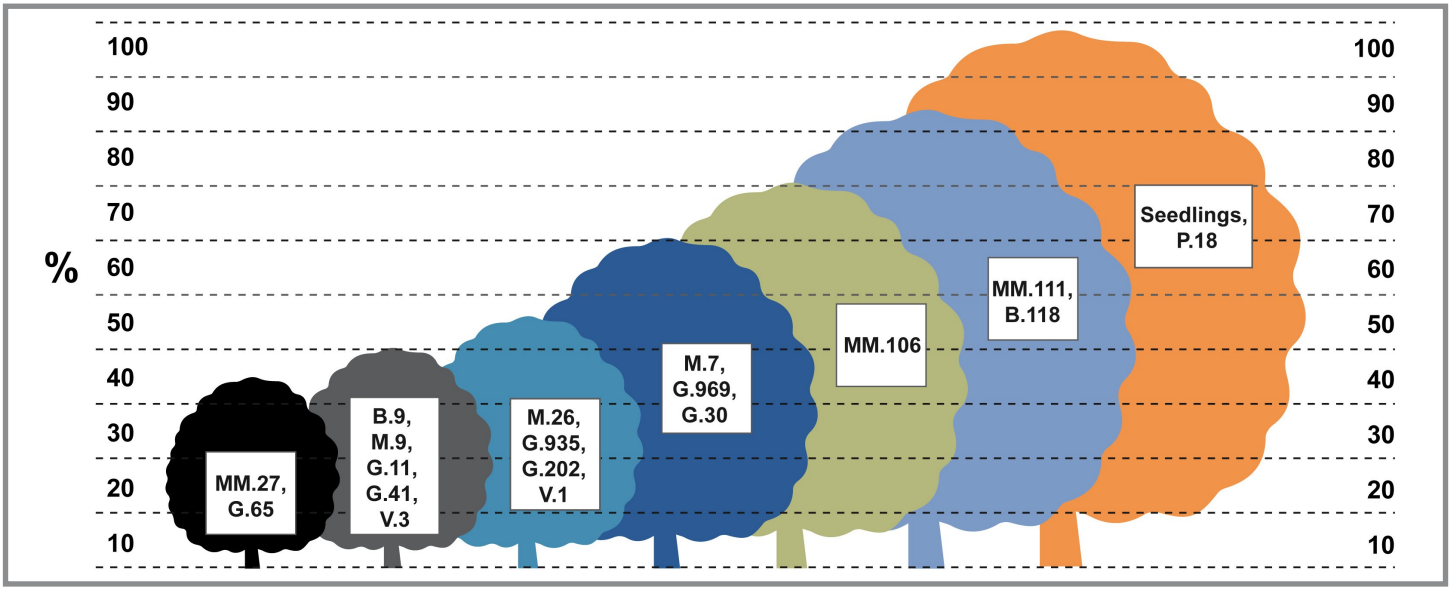

Figure 2. *Using different rootstocks to illustrate the different size comparisons based on percent size of standard apple seedling. Illustration by V. Kraus Nurseries, modified by Dr. M. Farcuh, University of Maryland*

production and used as a reference for comparison in NC -140 rootstock trials. M.26 is precocious and very productive. It is also more vigorous than M.9. Because M.26 produces many burr knots, growers should ensure that the union between the scion cultivar and the rootstock is no more than 1-2 inches above the soil level. Additionally, M.26 is susceptible to crown rot and fire blight. NC-140 scientists report incompatibilities between this rootstock and cultivars such as Rome, Stayman, Golden Delicious, and others in the NC-140 trials.

M.7 is categorized as a semi-dwarfing rootstock which is moderately precocious, i.e., M.7 is precocious but less than M.27 and M.9. This rootstock may require trunk support in shallow, rocky soils or with some particular cultivars. It can produce numerous suckers and is susceptible to collar rot.

M.2 can produce a semi-dwarf to semi-standard freestanding tree. M.2 is a strong rootstock that crops well, and is not susceptible to collar rot.

Malling-Merton Series

The Malling-Merton rootstocks were created by a joint effort of the East Malling Research Station and the John Innes Institute of Merton in England in 1917 to develop rootstocks resistant to the woolly apple aphid. This effort created two vigorous rootstocks which are still used to this day (in order from smallest to largest): MM.106 and MM.111.

MM.106 is a semi-dwarfing rootstock that is highly productive, does not require support, and is cold hardy. However, this rootstock is susceptible to tomato ringspot virus, fire blight, root rot, and crown rot, so it is not recommended for poorly draining sites. Consequently, growers have used fewer MM.106 rootstocks over the last 25 years.

MM.111 was a standard rootstock in the mid-Atlantic region in the 1970s and 1980s. It is one of the most vigorous semi-dwarfing rootstocks. It is productive, does not require support, is tolerant to drier soil conditions, and is very cold-hardy. It is resistant to woolly apple aphid and tolerant to fire blight and crown and root rots. It is crucial that when growers plant this rootstock, the union is not higher than 1-2 inches above the final soil line or its establishment will be affected. However, as growers have recently trended to planting higher density orchards, they are choosing to use MM111 less often.

Budagovsky Series

Researchers at Michurinsk University of Agriculture in the Soviet Union developed the Budagovsky series. These researchers developed these series with the goal of creating rootstocks with improved cold hardiness. The rootstocks in these series have leaves that are distinctively red. Some of the rootstocks in this series include (in order from smallest to largest): Budagovsky 9 (B.9), Budagovsky 10 (B.10), and Budagovsky 118 (B.118).

B.9 is a dwarfing rootstock and is seen as a replacement for M.9 in colder climates. Trees that are grafted on B.9 are 25-35% smaller than M.9EMLA and need to be supported. B.9 confers additional advantages such as early ripening time, increased yield, and increasing resistance to fire blight with age. It also appears to be resistant to collar rot.

B.10 rootstocks are cold hardy, yield efficient, fire blight tolerant, have good root anchorage and are tolerant to environmental stress. They are similar to M.9 as dwarfing-type rootstocks in terms of yield and tree size.

B.118 is a semi-dwarfing rootstock and is more vigorous than the other rootstocks in the series. Recognizing its vigor, growers recommend B.118's use for spur strains of apples (e.g., Fuji, Macintosh, Golden Delicious), for areas with soil with low fertility, or for replanting. It has a high degree of cold-hardiness, as evidenced by its ability to survive at temperatures as cold as -18.4°F with no root damage. B.118 is also early bearing. It has moderate resistance to fire blight but is susceptible to *Phytophthora*.

Geneva Series

Researchers at Cornell University in the United States and the USDA started developing the Geneva series in 1968. This series caters to conditions in eastern North America and is known for its high resistance to fire blight, woolly apple aphid, *Phytophthora* root rot, and replant disease. The Geneva series is widely used in the mid-Atlantic. Some of the Geneva rootstocks, from smallest to largest, include: G.65, G.11, G.16, G.41, G.214, G.935, G.202, G.969, G.30, G. 210, and G.890.

G.65 is a very dwarfing rootstock that is close in size to M.27. The rootstock is difficult to propagate in nurseries. It is susceptible to tomato ring spot virus and apple stem grooving virus. Results from the NC-140 have not recommended it for commercial plantings, although it can be used for residential plantings.

G.11 is a vigorous dwarfing rootstock, similar to M.9, and is widely used in the mid-Atlantic. It is resistant to fire blight and crown rot, and rarely produces burr knots or root suckers. It is precocious and cold hardy, but needs trunk support in early years.

G.16 is a dwarfing rootstock, which is similar to M.9 in terms of size, precocity, and need for support. It is resistant to fire blight and crown rot but is susceptible to woolly apple aphid and powdery mildew. G.16 is highly sensitive to latent viruses, so growers should use only virus-free budwood for its propagation. G.16 does not produce burr knots or root suckers.

G.41 is also a dwarfing rootstock and is the most widely available of the Geneva series. G.41 and M.9 are similar in size, but G.41 has a higher yield efficiency and produces fewer root suckers. It is highly resistant to fire blight, woolly apple aphids, and *Phytophthora*. It is tolerant to replant disease and is better suited to high pH soils. However, G.41 requires extra support because the graft is prone to breakage, particularly with scions such as Honeycrisp and Cripps Pink in high wind areas.

G.214 is a dwarfing rootstock that can produce a tree about 30-35% the size of Seedling. It has a precocity similar to M.9 and M.26, yet it is more productive and has good cold hardiness. G. 214 is resistant to fire blight, woolly apple aphid and *Phytophthora*. Trees on this rootstock require support.

G.935 is slightly larger in size than M.26 and has production efficiency similar to M.9. This rootstock is resistant to fire blight and crown rot, but not to the woolly apple aphid. G.935 is sensitive to latent virus, so growers should use only virus-free budwood for its propagation. Researchers from NC-140 have observed that this rootstock induces the production of wider branch angles in the scion.

G.202 is a semi-dwarfing rootstock that produces a tree that is both slightly larger and more productive than M.26. It is resistant to fire blight, to *Phytophthora*, and to woolly apple aphid. It seems to be a useful alternative to M.26 in climates that have problems with woolly apple aphids.

G.969 is a semi-dwarfing rootstock that is cold hardy; is resistant to fire blight, *Phytophthora*, and woolly apple aphid; and is ideal, based on NC-140 trials, for growers desiring a freestanding tree. It is classified as having growth control similar to M.7. G.969 rootstocks produce few root suckers or burr knots and are tolerant to replanting.

G.30 is a semi-dwarfing rootstock that produces a tree similar in size, precocity, and productivity to M.7. G.30 is highly resistant to fire blight and *Phytophthora*, but is susceptible to woolly apple aphid. It produces few suckers. NC-140 researchers have reported that G.30 has brittle wood, and thus when budded or grafted with brittle scions, such as Gala, the trees may break at the graft union during wind storms. Therefore, G.30 rootstocks are recommended by NC-140 researchers to be supported, particularly if using Gala as the scion.

G.210 is a semi-dwarfing rootstock which is similar in size to M.7, but is more productive and precocious. It is also resistant to fire blight and *Phytophthora*.

G.890 is a semi-dwarfing rootstock that is cold hardy, resistant to fire blight, *Phytophthora*, and wooly apple aphid. Tree size is similar to M.7/ MM.106, but it presents higher and earlier production. G.890 produces root suckers but there is no information on burr knot production.

Vineland Series

Researchers at the Horticultural Experiment Station at Vineland Station in Ontario, Canada developed the Vineland series of apple rootstocks in 1958. The Vineland series is known for increased cold hardiness and fire blight resistance compared to rootstocks like M.26. Two rootstocks resulting from this effort include (from smallest to largest) V.3 and V.1.

V.3 is a dwarfing rootstock that is highly commercially available and similar in size to M.9. V.3 displays the benefits of the Vineland series (cold hardy and resistant to fire blight), but compared to M.9, it has a lower cumulative yield yet a higher yield efficiency. NC-140 researchers have observed that V.3 produces low amount of root suckers or burr knots.

V.1 is a semi-dwarfing rootstock that is similar in size and cumulative yield and yield efficiency to M.26. V.1 has improved cold hardiness and somewhat better resistance to fire blight than M.26.

P Series

The Research Institute of Poland in Skierniewice, Poland developed and released the P series in 1954. The P series' characteristics include cold hardiness and resistance to

collar rot. Some rootstocks released by these series include (from smallest to largest) P.2 and P.18.

P.2 is a dwarfing rootstock. It is slightly more dwarfing but has a slightly higher yield efficiency than M.9 NAKB 337. It produces a low amount of root suckers and burr knots. P.2 is susceptible to fire blight, as well as to wooly apple aphid, but is highly resistant to collar rot.

P.18 is a standard-size rootstock with vigor similar to seedling, and is a good option for those who want a larger tree. P.18 is cold hardy, resistant to *Phytophthora*, and does not need tree support. However, it is susceptible to the wooly apple aphid and is moderately susceptible to fire blight.

Supporter Series

The Pillnitzer Supporter Series has been developed from the Institut fur Obstforschung Dresden-Pillnitz in Germany. Among the rootstocks released in this series, Supporter 4 is similar in vigor and anchorage to M.26. Its yield capacity in NC-140 trials has been better than that of M.26. Supporter 4's benefits include early precocity, good winter cold hardiness, and fewer burr knots than M.26. Trees grafted on Supporter 4 require a support structure.

Interstem

The interstem results from the combination of three different elements (Fig. 3):

- the primary vigorous rootstock underground or understock (usually MM.111 or MM.106),
- the dwarfing interstem wood portion in the middle (usually M.9 or M.27), and
- the scion cultivar grafted onto the interstem.

The height of the tree is controlled directly by the length of the interstem. Increasing the length of the interstem results in a greater dwarfing effect. Interstem trees should be planted so that a portion of the interstem is buried. Interstems can develop a strong root system but at the same time can limit the vigor or size of the whole tree. It is important to mention that interstem trees require an extra year in a nursery, often making it more expensive than a traditional rootstock.

The interstem series are generally coded by the industry as interstem/primary rootstock. Common combinations are M.9/MM.106, M.9/MM.111, M.27/MM.106, and M.27/MM.111. All of these have similar precocity, productivity, and cumulative yield to M.26. Of these four

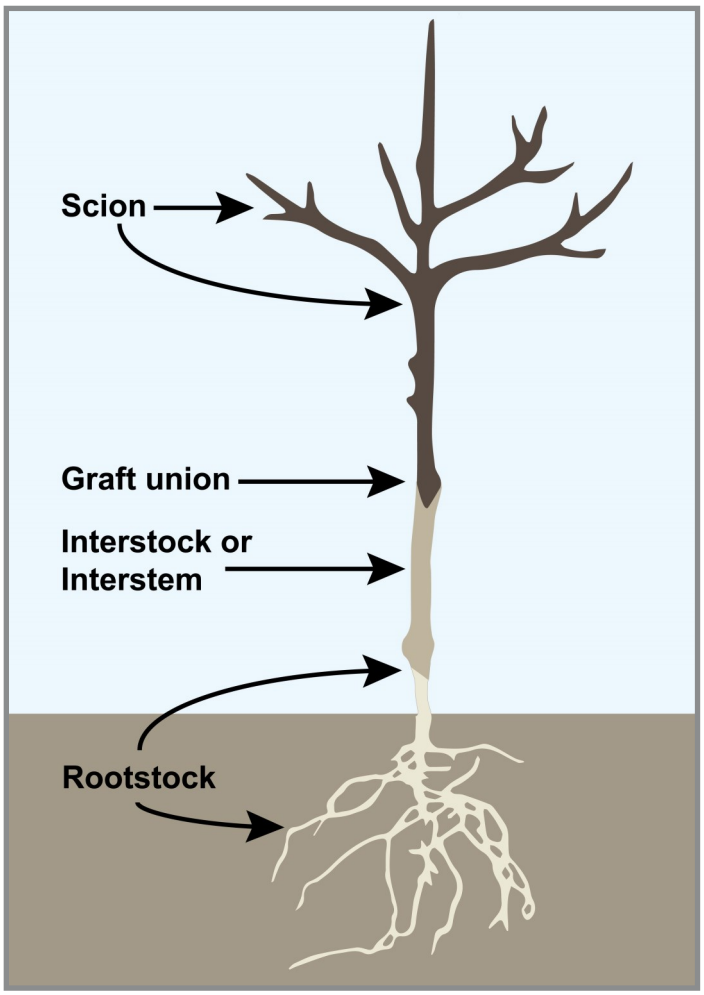

Figure 3. *Diagram of an interstem rootstock illustrating three key elements: scion, interstem and rootstock. Graphic by Alison O'Connor, USDA*

combinations, M.9/MM.106 has the highest cumulative yield, and M.9/MM.111 has the lowest cumulative yield.

Conclusions

In the last more than 30 years the number of rootstocks developed by breeding programs around the world and commercially available has been steadily increasing. The number of rootstocks developed by breeding programs around the world and that are commercially available has been steadily increasing over the last 50 years. This is due to the importance of rootstocks in the improvement of profitability, uniformity and economics on commercial apple orchards. There is not an ideal rootstock for all situations as their performance can be markedly affected by the environmental conditions under which they are grown. The NC-140 Multistate Research Project, which began in the late 1970s, has been leading the way on evaluating the capabilities and limitations of the new rootstocks established under different conditions

throughout North America, and on providing key recommendations to commercial apple growers. This effort will actively continue as more rootstocks are developed in the future.

For More Information

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