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New and Forthcoming Apple Rootstocks

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Apple rootstock breeding programs were initiated in England at John Innes and at East Malling in 1922 and 1924. Other rootstock breeding programs developed later in Germany, Sweden, Canada, the USSR, Poland, Czechoslovakia, Romania, the USA and most recently, Japan. From the English efforts, the Malling-Merton stocks and Malling 25 were introduced in 1952, M. 26 in 1965, and M. 27 in 1956. In the late 1940's, Alnarp 2 was introduced in Sweden, Robusta 5 and "Antonovka" in Canada, and PK-14 and Budagovsky 9 in the USSR (5).

Breeding programs for developing improved apple rootstocks have had a considerable range of objectives, mostly related to local problems. The English programs have tended to focus on productivity and tree size control, with considerable emphasis on adaptation to soil and pest problems (12). The projects in Canada, Sweden, Germany, Poland, Czechoslovakia, Romania and the USSR have emphasized winter hardiness, ease of propagation, and dwarfing. The rootstock breeding program initiated at Geneva in 1968 has a number of stated objectives, including both horticultural attributes and adaptations to those factors of the biotic and physical environment which tend to be limiting (6). Most of the rootstocks recently introduced have derived from one of these breeding programs.

Recent Introductions from Breeding Programs

Malling 27. This "super-dwarfing" clone produces a tree considerably smaller than a tree on M. 9. It is a hybrid of M. 13 × M. 9, bred at East Malling in 1929 and selected in 1934. Compared to M. 9, M. 27 is similarly resistant to crown rot and susceptible to fire blight and woolly apple aphids (WAA). It is slightly less tolerant of New York winters than is M. 9, and in the lower Midwest is frequently killed. Trees on M. 27 come into bearing very early and are highly productive. Suckering is very rare (13). A number of trees of 'Northern Spy' on M. 27 have broken off at the union. Propagation by stooling and by hardwood cuttings is about the same as for M. 9. In the USA, M. 27 is patented.

Bemali. A hybrid of Mank's Codlin × M. 4, this is the first introduction from the apple rootstock breeding program at Balsgard, Sweden. Bemali is about as dwarfing as M. 26. It was selected for its ease of propagation, freedom from WAA, thriftiness in nursery and orchard, and excellent productivity (9). Bemali has not yet been tested in the USA.

The Ottawa Series. A set of winter-hardy stocks was introduced by Agriculture Canada after extensive testing in Canada and at Geneva. The most

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dwarfing, Ottawa 3 (0.3), was selected from a Robin × M. 9 progeny (Robin is a hardy crab). Compared to M. 9, 0.3 appears to be not quite so dwarfing, better anchored and not nearly as brittle, as resistant to crown rot, similarly susceptible to fire blight and to WAA, and more difficult to propagate. Suckering is rare. Both micropropagation and root cuttage of 0.3 are being tested and may prove to be commercially useful approaches. This stock is sensitive to apple stem grooving virus. Trees on 0.3 have been highly productive in Canada and New York. It appears to have much promise as an interstem (8, 16).

Ottawa 8 was selected from a *M. baccata gracilis* × M. 7 progeny. Its tree size control compares with that of MM. 106, but O. 8 is much hardier. It is a fairly good propagator.

Ottawa 11 is an open-pollinated seedling of *M. baccata.* Burrknots are profuse and tend to coalesce, sometimes girdling or partially girdling the trunk. It is resistant to fire blight. Growth activity begins in early spring, with or before Robusta 5. This early activity combined with the excessive burrknotting may be related to the early decline reported in several midwestern states. In New York, both O. 8 and O. 11 have been excellent stocks for spur-type McIntosh.

The "P"-series. Test winters occur in Poland about 1 year in 10, and apple stocks must be adapted to this climate in which seedlings of Common Antonovka (Antonovka Obyknovennaja) are standard. From crosses of M. 9 × Common Antonovka, the Skierniewice station has introduced P-1, P-2, P-16 and P-22, and from M. 4 × Common Antonovka, P-18 (1, 11). The P-stocks have survived 2 very severe Polish winters. All have considerable resistance to crown rot. P-2, P-16 and P-22 are in the M. 9-M. 26 dwarfing class. P-1 appears to be similar to M. 7 for tree size control, and P-18 is about as vigorous as its M. 4 parent (1, 11). At Geneva, all but P-18 are as susceptible as M. 9 to fire blight; all are susceptible to WAA. We have experienced some difficulty in propagating the P-clones by stooling, although in Poland, established stoolbeds are productive. We have found P-16 to be unacceptably brittle, and Polish pomologists regard it as wintertender. Our preliminary observations indicate that Delicious on P-2 may be as badly damaged by tomato ringspot virus as is Delicious on MM. 106 (7).

The Budagovsky series. At the Michurin College of Horticulture south of Moscow, Budagovsky's primary objectives centered on adaptation to the severe climate of central Russia (2). His PK-14 and Red-Leafed Paradise (Budagovsky 9) were major steps forward, and his subsequent introductions have been marked by steady progress in winter hardiness and in horticultural excellence. In tests in Poland, Red-Leafed Paradise has been unusually resistant to crown rot (1). In Geneva tests, however, it was highly susceptible to WAA, to fire blight, to powdery mildew and to apple scab. The Red-Leafed Paradise in commerce carries the common latent viruses, to which it is tolerant; a virus-free strain is now being distributed to nurserymen. Red-Leafed Paradise is being very heavily used in Poland as an interstock; in New York, we have been impressed that the interstem develops no overgrowth and no burrknotts. Delicious and Northern Spy on Red-Leafed Paradise interstems begin bearing as early as trees on M. 9 interstems. Red-Leafed Paradise is very difficult to propagate by stooling, which has severely restricted its use.

Bud. 54-118 and Bud. 57-490 are vigorous stocks, similar in tree-size control to MM. 106. Bud. 57-490 induces very early production, as does MM. 106; Bud. 54-118 does not, and for that reason seems to us to offer no

advantage. Bud. 57-490 is unusual among clonal stocks in that burrknots rarely occur, yet is is easy to propagate by hardwood cuttings. Bud. 57-490 is crown rot resistant, moderately resistant to fire blight, and susceptible to WAA.

Bud. 54-146 is very dwarfing, about like M. 27. It is extremely brittle, has very many burrknots and is very susceptible to fire blight and to WAA. We see no promise in this selection.

Bud. 57-491 is also a very dwarfing stock, one of the most interesting from Budagovsky's breeding. It may be susceptible to crown rot, and is susceptible to fire blight and to WAA. It is highly tolerant to low winter temperatures, and therefore appears to us to be of special value as an interstem in regions with such climates. Bud. 57-491 propagates very easily in the stoolbed.

The North Caucasus introductions. At Krasnodar, USSR, breeders at the North Caucasus Pomological Institute (NCPI) crossed M. 9 and M. 4 with hardy local cultivars to obtain clonal stocks adapted to the climate of the Black Sea region (18). Except for the Russian evaluation on nursery and orchard performance, we know nothing about these stocks. Since they have not been exposed to WAA or fire blight, it is likely they will be susceptible to both. No deliberate attempt was made to select for crown rot resistance.

Pillnitz 80. In the 1930's, Schindler (15) in eastern Germany made a number of crosses including Paradise × Doucin (probably M. 9 × M. 2). From this family there was selected a clone, designated PiR 80 (and sometimes Pi 80), which is about as dwarfing as M. 9, highly productive, and quite easily propagated. This clone has been tested at East Malling Research Station as an interstem. We have not acquired Pi 80 at Geneva.

Selections from Open-Pollinated Seedlings

Mark. Introduced in 1980 by Michigan State University, Mark was earlier described and distributed for testing as MAC-9 (4). Mark arose as an open-pollinated seedling of M. 9. It is described by the originator, Dr. Robert Carlson, as capable of producing a free-standing tree about as dwarfed as a tree on M. 9 or M. 26; propagation is similar to that of M. 9. Compared to M. 9, at Geneva Mark is about as susceptible to fire blight and to WAA. Preliminary evidence suggests that Mark may respond to tomato ringspot virus as does MM. 106; further work will be required to define this relationship. Mark will be patented in the USA. Other more vigorous stocks in the MAC series may be of interest to the breeder.

YP. Selected in Finland from a large number of open-pollinated seedlings of *M. baccata,* YP is said to be easy to propagate asexually (14). It is a vigorous stock, producing standard size trees. Scion cultivars on YP harden quite early in the fall. The rootstock itself is very tolerant of Finnish winters, in which sudden early fall freezes are as important as the deep midwinter cold. We have just begun testing YP at Geneva; in our first tests, YP shoots were very susceptible to fire blight.

Jork 9 (J9). The fruit research station at Jork, West Germany, has just released this selection from open-pollinated M. 9 seedlings (17). After 20 years' testing, J9 appears to be much more easily propagated, and at least as productive as its seed parent. Burrknots are numerous. J9 is hardier than M. 9 but less hardy than M. 11. We have not yet acquired J9 for testing; however, it is probable that it will be as susceptible to fire blight and to WAA as is M. 9. J9 is moderately susceptible to scab and powdery mildew.

OAR-1. In Oregon plantings of Gravenstein on domestic seedling stocks

Horticultural Characteristics of Some New Rootstock Candidates

(Exc = Excellent; VG = Very Good; M = Intermediate; MS = Moderately Severe; S = Severe; VS = Very Severe; NT = Not Tested.)

	Precoc. Ind.	Prod. Ind.	Anch.	Sucker Prod.	Prop.	Compat.	Brittle
Vigorous Rootstocks							
Alnarp 2 (A2)	G	G	Exc	M	VG	VG	Exc
Antonovka (KA)	NT	NT	NT	NT	NT	G	Exc
YP (Mb-4)	VG	VG	VG	NT	G	G	NT
Novole	G	NT	VG	VG	Exc	G	Exc
Semi-Vigorous Stocks							
MM. 106	Exc	Exc	G	VG	VG	Exc	Exc
Bud. 54-118	G	G	VG	VG	G	G	VG
Bud. 57-490	VG	Exc	VG	VG	Exc	NT	VG
I-48-46 (NCPI)	NT	NT	NT	NT	NT	NT	NT
P-18	VG	VG	NT	NT	M	NT	Exc
Ottawa 8	G	VG	Exc	G	G	NT	Exc
Ottawa 11	G	VG	G	NT	VG	NT	VG
Semi-Dwarf							
M. 26	VG	VG	MS	G	MS	G	G
Bud. 9 (RLP)	VG	Exc	MS	VG	VS	VG	MS
II-25-23 (NCPI)	NT	NT	NT	NT	NT	NT	NT
P-1	G	G	NT	VG	G	G	G
P-16	VG	VG	MS	NT	VG	NT	VS
Ottawa 3	Exc	Exc	M	VS	NT	G	NT
Jork 9 (J9)	VG	VG	G	NT	VG	NT	NT
Bemali	VG	VG	NT	NT	Exc	NT	NT
Dwarf							
M. 9	Exc	Exc	S	S	M	G	S
I-47-1 (NCPI)	NT	NT	NT	NT	NT	NT	NT
M. 20	Exc	Exc	MS	NT	G	NT	M
Mark (MAC-9)	Exc	Exc	G	G	VG	G	M
OAR-1	NT	NT	G	G	NT	NT	G
P-2	Exc	Exc	G	G	M	NT	M
P-22	Exc	Exc	G	G	M	NT	M
Pi 80 (Pillnitz)	G	G	NT	NT	G	NT	NT
Super-Dwarf							
M. 27	Exc	Exc	S	G	G	MS	M
Bud. 54-146	VG	VG	VS	MS	Exc	NT	VS
Bud. 57-491	Exc	Exc	G	G	VG	NT	MS

Responses of Rootstock Candidates to Physical Factors of Environment

(Exc = Excellent; VG = Very Good; VS = Very Susceptible; S = Susceptible; MS = Moderately Susceptible; M= Intermediate; NT = Not Tested.)

	Early Freezes	Mid-Winter	Fluct. Temps.	Drought	Wet Feet	High pH
	Vigorous Rootstocks					
Alnarp 2 (A2)	MS	Exc	NT	NT	NT	NT
Antonovka (KA)	NT	NT	NT	NT	NT	NT
YP (Mb-4)	Exc	Exc	NT	NT	NT	NT
Novole	M	M	NT	NT	NT	NT
	Semi-Vigorous Stocks					
MM. 106	VS	MS	G	M	S	G
Bud. 54-118	G	VG	NT	NT	NT	NT
Bud. 57-490	G	Exc	NT	NT	NT	NT
I-48-46 (NCPI)	NT	NT	NT	NT	NT	NT
P-18	NT	VG	NT	NT	NT	NT
Ottawa 8	NT	VG	NT	NT	NT	NT
Ottawa 11	NT	VG	S	NT	NT	NT
	Semi-Dwarf					
M. 26	M	G	G	S	VS	NT
Bud. 9 (RLP)	G	G	G	NT	NT	NT
II-25-23 (NCPI)	NT	NT	NT	NT	NT	NT
P-1	NT	G	NT	NT	NT	NT
P-16	NT	MS	NT	NT	NT	NT
Ottawa 3	G	VG	NT	NT	NT	NT
J9	NT	G	NT	NT	NT	NT
Bemali	NT	G	NT	NT	NT	NT
	Dwarf					
M. 9	G	MS	M	M	M	NT
I-47-1 (NCPI)	NT	NT	NT	NT	NT	NT
M. 20	NT	NT	NT	NT	NT	NT
Mark (MAC-9)	NT	NT	NT	NT	NT	NT
OAR-1	NT	NT	NT	NT	NT	NT
P-2	G	VG	NT	NT	NT	NT
P-22	G	VG	NT	NT	NT	NT
Pi 80 (Pillnitz)	NT	NT	NT	NT	NT	NT
	Super-Dwarf					
M. 27	M	MS	NT	NT	NT	NT
Bud. 54-146	NT	G	NT	NT	NT	NT
Bud. 57-491	G	VG	NT	NT	NT	NT

Responses of Rootstock Candidates to Biotic Factors of Environment

(VS = Very Susceptible; S = Susceptible; MS = Moderately Susceptible; M = Intermediate; MR = Moderately Resistant; R = Resistant; VR = Very Resistant; NT = Not Tested.)

	Crown Rot	Fire Blight	Powdery Mildew	White Root Rot	Woolly Aphids	Common Latent Viruses	TmRSV
	Vigorous Rootstocks						
Alnarp 2 (A2)	MS	VS	MS	NT	S	Tol.	NT
Robusta 5 (R5)	M	VR	MR	NT	VR	MS	G
Antonovka (KA)	NT	MS	NT	NT	MS	NT	NT
YP (Mb-4)	NT	VS	NT	NT	NT	NT	NT
Novole	Res.	Res.	MR	NT	MR	S	G
	Semi-Vigorous Stocks						
MM. 106	S	MS	S	MS	Res.	Tol.	VS
Bud. 54-118	NT	MS	NT	NT	S	NT	NT
Bud. 57-490	MR	M	S	NT	MS	NT	NT
I-48-46 (NCPI)	NT	NT	NT	NT	NT	NT	NT
P-18	VR	MR	M	NT	S	NT	NT
Ottawa 8	NT	M	M	NT	M	M	NT
Ottawa 11	NT	MR	M	MR	M	M	G
	Semi-Dwarf						
M. 26	M	VS	M	NT	VS	MR	S
Bud. 9 (RLP)	VR	S	MS	NT	S	Tol.	NT
II-25-23 (NCPI)	NT	NT	NT	NT	NT	NT	
P-1	MR	MS	NT	NT	MS	NT	NT
Ottawa 3	Res.	S	M	NT	VS	M	NT
J9	NT	NT	MS	NT	NT	NT	NT
Bemali	NT	NT	NT	NT	MR	NT	NT
	Dwarf						
M. 9	Res.	VS	M	NT	S	Tol.	NT
I-47-1 (NCPI)	NT	NT	NT	NT	NT	NT	NT
M. 20	NT	NT	NT	NT	NT	NT	NT
Mark (MAC-9)	NT	S	M	NT	MS	Tol.	MS
OAR-1	NT	MS	NT	NT	M	NT	NT
P-2	Res.	MS	NT	NT	MS	NT	S
P-22	Res.	MS	NT	NT	MS	NT	NT
Pi 80 (Pillnitz)	NT	NT	NT	NT	NT	NT	NT
	Super-Dwarf						
M. 27	Res.	S	M	NT	S	Tol.	NT
Bud. 54-146	NT	VS	MS	NT	S	NT	NT
Bud. 57-491	MS	S	MS	NT	S	NT	NT

made in 1943 and 1948, many trees were blown down by high winds in 1962. Among the survivors was a conspicuously dwarfed tree which was very productive. Suckers from the stock of this tree have been propagated as OAR-1 (Oregon Apple Rootstock No. 1). At Geneva, OAR-1 has been susceptible to WAA and moderately susceptible to fire blight. The stock has been as precocious as M. 9.

Novole (PI 286613). This Geneva selection from a set of open-pollinated seedlings of *M. prunifolia* from Japan will be introduced and patented in 1982 for use as a root- and trunkstock system relatively unpalatable to pine voles and meadow voles (3, 10). The putative pollen parent is *M. sieboldii;* morphologically this selection appears to fit the description of the interspecific hybrid, *M. X sublobata.* This clone has been used very heavily in the Geneva apple rootstock breeding program because it transmits to progeny its resistance to crown rot, fire blight and tomato ringspot virus. As a rootstock, Novole is very vigorous but production of Northern Spy begins earlier on Novole than on domestic seedling stocks. We have never observed burrknots on this selection, yet it is more easily propagated by cuttings than any other stock with which we have worked.

The "Antonovka" group. Although treated in western countries as a cultivar name, "Antonovka" is better considered a collective appellation. Thus Common Antonovka (Antonovka Obyknovennaja) in Poland and the USSR does apparently identify a single fruiting cultivar or perhaps a group of very similar clones. We have in our Geneva collection 9 "Antonovka" clones, including Antonovka Kamenichka, which is fire blight resistant; Antonovka Polutorafuntonaja, which has polygenic scab resistance but is very susceptible to fire blight; and Antonovka Zheltinaja, which is susceptible to about everything. In 1946, the Ottawa station introduced a selection of open-pollinated "Antonovka" (probably Antonovka Polutorafontanaja) for use as a hardy rootstock. Recently Adams Nurseries in Washington State have made selections from open-pollinated Antonovka from Poland (these are the "KA-" selections).

Most of the so-called Antonovkas are winter-hardy. All we have tested are susceptible to WAA, and all except Antonovka Kamenichka are susceptible to fire blight. Resistance to crown rot is highly variable; KA 313 appears to be resistant.

Conclusions

The spectrum of new apple rootstocks becoming available or soon to be in the commercial picture is far greater than any in recent experience. Although several research institutions are involved in rootstock testing, we are concerned with the general dearth of information on the interactions between the stock and its environment. Horticultural traits — propagability, precocity induction, tree size control— have generally been worked out by the introducer, but objective assessments of responses to limiting factors of biotic and physical environments are sadly lacking.

Extensive orchard trails of many of these stocks have been initiated by the NC-140 technical committee, a group of some 25 scientists from as many stations. This work is sponsored in part by the fruit industry, through the International Dwarf Fruit Tree Association. Evaluation of interactions with specific environmental factors is also proceeding at Geneva, and at stations in North Carolina, West Virginia, Arkansas and Texas.

By the year 2000, some few of the stocks listed here will be commercially important. Which of these stocks are most likely to be retained?

Among the most vigorous (standard) stocks, Geneva's Novole (PI 286613) is our favorite candidate. It appears to have unusual capacity to survive

environmental challenges—crown rot, fire blight, and voles especially. Horticulturally it appears satisfactory. Its sensitivity to the common latent viruses might be considered a deficiency, but this problem is easily avoided by utilizing virus-free scionwood.

Both P-18 and Budagovsky 57-490 are likely to win places in our future repertoire, replacing MM. 106. Both appear to be resistant to crown rot, both appear very tolerant of low winter temperatures, and both induce heavy, early cropping. That Bud. 57-490 is so easy to propagate will certainly make it the nurseryman's choice.

Competition in the M. 26 to M. 7 size range is rigorous. If propagation techniques can be developed for Bud. 9, it would be an extremely useful stock in some applications, but we would favor Ottawa 3. Bemali offers significant possibilities also, but too many of its environmental adaptations have not been defined.

Mark and P-22 are most likely to dominate the M. 9 size class. Its ease of propagation makes Mark especially interesting to nurserymen. That its anchorage is good makes Mark attractive to orchardists. Both these stocks, however, are far more susceptible to fire blight than we find acceptable. In fact, among the several dwarfing candidates, only OAR-1 is even minimally tolerant of this critically important disease.

We do not see any fully satisfactory "super-dwarfing" stock. Malling 27 is unlikely to survive severe winter temperatures. Bud. 54-146 is excessively brittle and very susceptible to fire blight. Bud. 57-491 appears the most promising, but we are concerned that crown rot problems may develop.

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