HortScience 33(4):641–643. 1998.

Performance of Eight Apomictic Selections as Apple Rootstocks

David C. Ferree

Horticulture and Crop Science, The Ohio State University, Ohio Agricultural Research and Development Center, Wooster, OH 44691

Additional index words. Malus ×domestica, Malus sargenti, Malus sieboldii, Malus hupehensis, internal bark necrosis, Mn toxicity

***Abstract.* The apple (*Malus ×domestica* Borkh.) cultivars Starkspur Supreme Delicious and Melrose were planted in 1987 on eight apomictic apple rootstock selections made in Germany by Dr. Hanna Schmidt and on M.7. Selections 2 [*M. hupehensis* (Pamp.) Rehd. parentage] and 8 [*M. sieboldii* (Regel) Rehd. parentage] were similar to M.7 in precocity, cumulative yield per tree, and yield efficiency, while the other selections with *M. sargenti* Rehd. in their parentage were slower to flower and had lower yields and yield efficiencies. Selections 2 and 8 tended to result in larger trees than M.7, while the selections with *M. sargenti* parentage were generally similar to M.7 in size. Except for trees on M.7 and selection 2, 'Starkspur Supreme Delicious' developed more severe symptoms of internal bark necrosis (IBN) than did 'Melrose', which normally does not show IBN. However, 'Melrose' showed IBN symptoms on selections with *M. sargenti* parentage. IBN symptoms were positively correlated with leaf Mn concentrations. Influence of rootstocks on other nutrient elements, although significant, were small compared to the effect on Mn. A significant interaction occurred between cultivar and rootstock in their effects upon branch morphology, mostly because fewer flowering spurs and more vegetative spurs were observed on 'Melrose' than on 'Starkspur Supreme Delicious' when grafted on Selection 2. These apomictic selections offered no advantage over M.7 as rootstocks for apples.**

Malus sargenti forms a small, compact tree ≈3 m tall at maturity. In the collection of crabapples in the Secrest Arboretum at Ohio Agricultural Research and Development Center in Wooster, Ohio, it very rarely shows fireblight symptoms. Most of the commercially available dwarfing rootstocks are very susceptible to fireblight (Ferree et al., 1983; Perry, 1992). Since fireblight has resulted in significant tree losses, the use of *M. sargenti* as a potential dwarfing rootstock was appealing. *Malus sargenti* is very susceptible to latent viruses found in many commercial apple cultivars and bud take with commercial cultivars is low (Schmidt, 1972a, 1972b). However, *M. sargenti* selections that were tolerant of latent viruses found in commercial apple cultivars were identified by Schmidt (1972b, 1982), who made eight of these selections available to test as rootstocks in Ohio. Six of the eight apomictic selections have *M. sargenti* in their parentage, while selections 2 and 8 have other apomictics as parents (Table 1). Early work in Ohio showed that these apomictic selections could be successfully micropropagated, although they differed in both proliferation and rooting ability (Miller and Ferree, 1988). The objectives of the study were to determine if the apomictic rootstocks were dwarfing and precocious, and if they survived under conditions with natural fireblight pressure.

Received for publication 23 Sept 1997. Accepted for publication 5 Nov. 1997. Salaries and research support provided by State and Federal funds appropriated to the Ohio Agricultural Research and Development Center, The Ohio State Univ. Manuscript No. 106-97. The cost of publishing this paper was defrayed in part by the payment of page charges. Under postal regulations, this paper therefore must be hereby marked *advertisement* solely to indicate this fact.

Materials and Methods

Seed from the apomictic selections (Table 1) were stratified and then planted in flats in the greenhouse in 1984. As the seedlings developed, off-type plants were rogued. The seedlings were transplanted to 7-cm pots and subsequently to a field nursery. In Aug. 1985, the seedlings were budded to 'Melrose' or 'Starkspur Supreme Delicious'. Finished trees were dug in Fall 1986 and placed in an underground storage until spring. Trees of the same cultivars on M.7 rootstock were purchased from a commercial nursery to serve as standards. In Mar. 1987, the trees were spaced 4 × 6 m and arranged as a split plot with cultivar as the main plot and apomictic rootstock selection as the split plot with eight single-tree replications. Trees were trained as freestanding central leaders with minimal pruning. Soil management was by herbicide strip and pesticides were applied as needed. The soil was Wooster silt loam (fine loamy mixed mesic typic fragiudalf) with a pH of 6.0.

Trunk circumference and yield were measured annually. The first significant bloom occurred in 1990 and flower clusters per tree were counted. Internal bark necrosis was evaluated annually after 1994 using two independent evaluators and a rating system of 1 = no symptoms through 10 = tree death. In mid-August, 20 mid-terminal shoot leaves were collected from each tree, dried in a forced-draft oven at 65 °C, ground through a 40-mesh screen, and submitted to the Ohio State Univ. Research and Extension Analytical Laboratory for nutrient analysis using an inductively coupled plasma (ICP) spectrophotometer (Watson and Isaac, 1990). Due to the cost, only five replications were used for nutrient analysis. In 1995, five shoots around the periphery of each tree were selected at bloom. The length of these branches was measured and the number of flowering and nonflowering spurs (<5 cm) and shoots (5 cm or longer) counted.

Results and Discussion

Trees on selections 2 and 8 were similar to trees on M.7 in precocity and early fruit set, while selections with *M. sargenti* in their parentage were usually slower to flower and generally had lower fruit set (Table 2). The two cultivars had similar numbers of flower clusters at the beginning of their fourth growing season and, although 'Starkspur Supreme Delicious' had greater fruit set than 'Melrose', neither cultivar was very precocious. 'Melrose' produced larger trees than 'Starkspur Supreme Delicious' and had higher yields/tree, but the cultivars did not differ in cumulative yield efficiency [yield/unit trunk cross-sectional area (TCA)]. Trees propagated on selections 2 and 8 were larger than those on M.7, while trees on selections with *M. sargenti* parentage were generally similar to M.7 in size. Olien et al. (1986) reported that nonspur-type 'Delicious' trees on *M. sargenti* were ≈60% the size of trees on apple seedling rootstock. This is consistent with the work reported here, since trees on M.7 are ≈60% the size of trees on apple seedling (Ferree et al., 1974; NC-140, 1991b).

Trees on selections 2 and 8 had higher cumulative yield/tree than trees on M.7 for both cultivars, but yield efficiency for these selections was similar to M.7 (Fig. 1 A and B). The difference between cultivars for cumulative yield per tree and yield efficiency was less on selection 8 than on any other rootstock tested. Yield per tree and yield efficiency of selections with *M. sargenti* parentage were lower than those of trees on M.7. Olien et al. (1986) reported a 40% increase in yield efficiency of 'Delicious' trees on *M. sargenti*

Table 1. Parentage of apomictic rootstock selections provided by Dr. Hanna Schmidt, BornKampsveg, Germany.

1. Seedling of pentaploid hybrid between *Malus sargenti* and 'Croncels' (D1106)
2. Hybrid of *M. hupehensis* and 'James Grieve' (D2032)
3. *Malus sargenti* open-pollinated second generation (C1812)
4. *Malus sargenti* open-pollinated (C1828)
5. *Malus sargenti* open-pollinated (C1827)
6. Tetraploid seedling (*M. sieboldii* x 'Husmodier') x *M. sargenti* (C0725)
7. *Malus sargenti* open-pollinated (C1826)
8. Tetraploid *M. sieboldii* open-pollinated (D2212)

Table 2. Influence of apple cultivar and rootstock on precocity and tree size. Rootstocks 1–8 apomictic. Trees planted in 1987.

	Flower clusters/ tree 1990	Fruit/100 flower clusters, 1990	Tree size 1997 Height (m)	Spread (m)	TCA[z] (cm^2)
Cultivar					
Starkspur Supreme Delicious	67.6	28.2	4.2	3.3	106.1
Melrose	76.0	14.8	4.7	4.0	157.4
Rootstock					
8	93.6 ab[y]	22.2 a–c	4.8 a	4.3 a	165.0 a
2	101.9 a	34.1 a	4.7 ab	3.9 b	161.0 ab
6	59.3 cd	14.8 c	4.6 ab	3.7 b–d	146.8 b
M.7	89.5 ab	28.7 ab	4.2 c	3.8 bc	127.0 c
1	61.5 cd	11.5 bc	4.4 bc	3.5 c–e	127.4 c
4	70.4 b–d	12.1 c	4.2 c	3.3 e	118.1 cd
3	74.6 a–c	17.0 bc	4.4 bc	3.5 de	116.7 c–e
7	43.4 d	21.7 bc	4.2 c	3.5 c–e	115.5 cd
5	52.1 cd	24.0 a–c	4.3 bc	3.3 e	106.3 d
F significance					
CV	NS	**	**	**	**
Selection	**	**	**	**	**
CV × Selection	NS	NS	NS	NS	NS

[z]TCA = trunk cross-sectional area.
[y]Mean separation within columns by DMRT, $P \leq 0.05$
[NS, *, **]Nonsignificant or significant at $P < 0.05$ and 0.01, respectively, by analysis of variance.

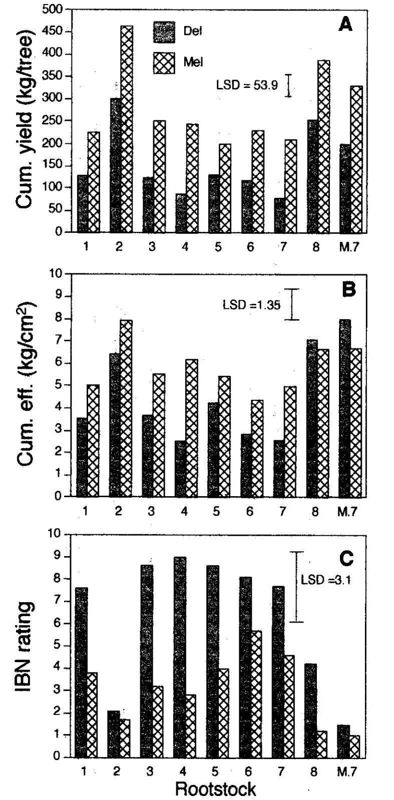

Fig. 1. Interaction of apple cultivar and rootstock on cumulative yield/tree (**A**) and cumulative efficiency (**B**) 1987–96, and IBN rating for 1995 (**C**) (1 = no symptoms to 10 = tree death).

compared with that of trees on seedling. Trees on M.7 generally have greater yield efficiency than trees on apple seedling rootstock, but are not as efficient as some of the more dwarfing rootstocks (Ferree et al., 1974; NC-140, 1991b).

Symptoms of IBN, generally thought to be due to Mn toxicity (Ferree and Thompson, 1970), appeared in some of the 'Starkspur Supreme Delicious' on selection 6 in the nursery. Symptoms developed on trees of a number of the other selections in the field and became particularly obvious after the drought in 1991. Ratings of IBN in 1989, 1994, 1995, and 1996 indicated that the symptoms became continually worse, reaching a peak in 1995, but the relative ranking of the rootstocks did not change. The 1995 IBN rating indicated that, except for trees on M.7 and selection 2, 'Starkspur Supreme Delicious' had much more severe symptoms than did 'Melrose' (Fig. 1C). This difference between cultivars was particularly marked in selections 3, 4, and 5. Normally, cultivars other than 'Delicious' do not exhibit symptoms of IBN (Ferree and Thompson, 1970), and symptoms have not been previously observed on 'Melrose', which has been grown for many years in Ohio. The most severe symptoms on 'Melrose' occurred on selection 6, which had the highest leaf concentration of Mn (Table 3).

All of the trees propagated on apomictic selections with *M. sargenti* in their parentage had very severe symptoms of IBN, with significant dieback of shoots and limbs and severe bark cracking. In contrast, trees on M.7 showed almost no symptoms of IBN and had the lowest leaf Mn concentrations of all the rootstocks in this trial. Trees on selections 2 and 8 had slightly higher leaf Mn concentrations than did those on M.7, and also, although not statistically significant, slightly higher IBN symptoms. In the Arkansas planting of the NC-140 trial, M.7 ranked in the second most tolerant group of rootstocks to IBN symptom development, along with MAC.24, M.26EMLA, O.3, M.9EMLA and M.27EMLA (NC-140, 1991a). A ranking of the rootstocks in the current trial from highest to lowest for both IBN and leaf Mn concentration shows the same order and a very close association with a significant correlation coefficient ($r = 0.66$). IBN was also significantly negatively correlated with the following: average fruit size ($r = -0.52$); cumulative yield ($r = -0.77$); and cumulative efficiency ($r = -0.76$). In an attempt to see if the ratios of other elements related to IBN, correlations were calculated; the highest of these were Ca/Mn ($r = -0.64$) and Mn/(K/Mg) ($r = 0.59$). In previous studies on IBN, IBN normally declined as tissue Ca increased (Ferree and Thompson, 1970).

A summary of the effects of nine rootstocks on foliar nutrient levels indicated that rootstock had a significant effect in some years, but differences were small and no rootstock resulted in nutrient levels in the deficiency range (Rom et al., 1991). In the NC-140 study, site or year generally accounted for more of the variability in leaf nutrient levels than did rootstock. In the present study rootstock had a significant influence on all the elements except Zn, Al, and Na (Table 3). Difference in extremes for N, P, K, and Ca were 12% or less, while slightly greater differences existed for the micronutrients. The greatest difference between extremes was for Mn (62%). Significant interactions were found for leaf K, Ca, and Mg (data not shown). 'Melrose' had slightly higher leaf K than 'Starkspur Supreme Delicious', except on selection 4, in which the concentrations were almost identical. 'Starkspur Supreme Delicious' had a higher leaf Ca level on M.7 than did 'Melrose', while for all other stocks they were equal or 'Melrose' had slightly higher concentrations. Leaf Mg levels were higher in 'Starkspur Supreme Delicious' than in 'Melrose' for all rootstocks except selections 2 and 4, where they were equal. Data for these significant interactions are not presented.

A study over 6 years of the influence of 17 rootstocks on branch morphology indicated that rootstock influenced shoot length, spur density, and flower density and that these factors were related to precocity and productivity (Hirst and Ferree, 1995). A significant interaction occurred between cultivar and rootstock for shoot length, flowering spur density, and vegetative spur density (Fig. 2). The length of the 2-year-old branch section on 'Starkspur Supreme Delicious' was longer than on 'Melrose' for apomictic selections 3, 4, 5, 6, 7, while shoot length was equal for the other rootstocks (Fig. 2A). This may have been partially due to the dieback of some branches on 'Starkspur Supreme Delicious' due to IBN, with the result that only the most vigorous branches were left to measure. As expected, 'Starkspur Supreme Delicious', due to its spur-type growth habit, had a greater density of flowering spurs than did 'Melrose' (Fig. 2B). The difference between cultivars was particularly marked in selection 2. Although vegetative spur density was generally greater with 'Melrose', the difference was again most dramatic with selection 2.

Over the 10 years of the study, fireblight occurred several times, with numerous strikes occurring on the 'Melrose' trees and only occasional strikes on 'Starkspur Supreme Delicious'. No tree death resulted due to fireblight. The apomictic selections in this trial offered no advantage over M.7 as a rootstock. To the author's knowledge, this is the first report of the increased uptake of Mn when rootstocks have *M. sargenti* in their parentage. Unfortunately, despite the very dwarf tree structure of *M. sargenti*, this rootstock did not result in sufficient dwarfing potential when commercial apple cultivars were grafted onto it.

Table 3. Effect of rootstock on 3-year averages of foliar nutrition levels of 'Starkspur Supreme Delicious' and 'Melrose' apples. Rootstocks 1–8 apomictic.

	% Dry mass[z]					Dry mass (mg·g^{-1})						
	N	P	K	Ca	Mg	Mn	Fe	B	Cu	Zn	Al	Na
Cultivar												
Starkspur Supreme Delicious	2.13	0.14	1.42	0.95	0.26	253	78	29	5.8	213	159	23
Melrose	2.02	0.13	1.64	0.99	0.24	250	71	24	5.8	255	171	32
Rootstocks												
1	2.10 a–c	0.139 ab	1.63 a	0.92 c	0.220 f	278 b	80 ab	27.2 cd	5.9 a	241	168	26
2	2.05 b–d	0.135 bc	1.47 d	1.03 ab	0.265 ab	165 d	66 e	27.1 cd	5.7 a	237	166	28
3	2.05 b–d	0.138 ab	1.60 ab	0.93 c	0.235 ef	283 b	76 a–c	26.5 de	6.8 a	233	169	28
4	2.12 ab	0.141 ab	1.52 b–d	0.96 bc	0.249 cd	289 b	81 a	26.2 de	5.8 a	238	162	28
5	2.14 a	0.137 bc	1.49 cd	0.95 bc	0.258 b–d	280 b	76 a–d	26.3 de	5.9 a	231	167	27
6	2.02 de	0.140 ab	1.53 b–d	1.06 a	0.262 bc	315 a	70 c–e	28.4 ab	5.2 b	230	166	27
7	2.13 ab	0.139 ab	1.53 b–d	0.93 c	0.252 b–d	289 b	76 a–c	25.7 e	6.0 a	232	163	29
8	2.03 c–e	0.145 a	1.57 a–c	1.04 a	0.244 de	243 c	73 b–e	29.5 a	5.7 a	241	168	29
M.7	1.97 e	0.131 c	1.46 d	0.92 c	0.279 a	121 e	67 de	27.9 bc	6.0 a	223	155	27
F significance												
CV	**[x]	**	**	**	**	NS	**	**	NS	**	**	**
Selection	**	**	**	**	**	**	**	**	**	NS	NS	NS
CV × Selection	NS	NS	**	*	*	NS	NS	NS	NS	NS	NS	NS

[z]Mean separation within columns by Duncan's multiple range, $P \leq 0.05$.

[NS, *, **]Nonsignificant or significant at $P < 0.05$ or 0.01, respectively, by analysis of variance.

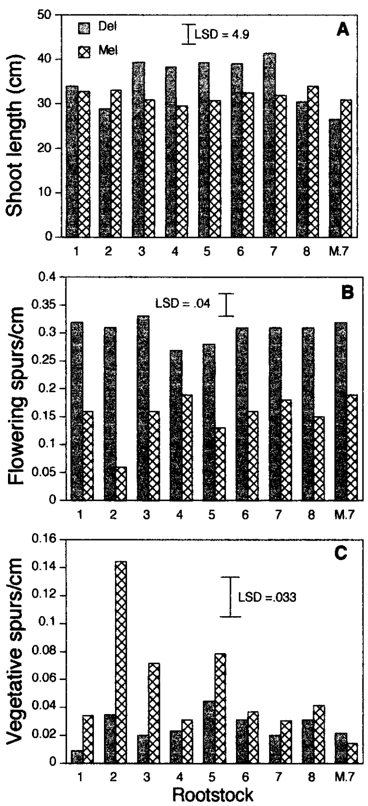

Fig. 2. Interaction of apple cultivar and rootstock on length of 2-year-old shoots (**A**), flowering spurs/cm (**B**), and vegetative spurs/cm (**C**) in 1995.

Literature Cited

Ferree, D.C. and A.H. Thompson. 1970. Internal bark necrosis of the apple as influenced by calcium placement and soil manganese. Maryland Agr. Expt. Sta. Bul. A-166.

Ferree, D.C., R.G. Hill, Jr., and E.K. Alban. 1974. Influence of rootstocks and herbicides on apple tree growth. Ohio Agr. Res. and Devel. Ctr. Res. Sum. 75:1–3.

Ferree, D.C., M.A. Ellis, and F.R. Hall. 1983. Tree loss to fireblight infection of rootstocks and interstems in Ohio apple orchards. Compact Fruit Tree 16:116–120.

Hirst, P.C. and D.C. Ferree. 1995. Rootstock effects on shoot morphology and spur quality of 'Delicious' apple and relationships with precocity and productivity. J. Amer. Soc. Hort. Sci. 120:622–634.

Miller, D.D. and D.C. Ferree. 1988. Micropropagation of apomictic *Malus* clones of diverse ploidy level and parentage. Fruit crops 1987: A summary of research. Ohio Agr. Res. and Devel. Ctr. Res. Circ. 295:42–45.

NC-140. 1991a. Abnormalities in 'Starkspur Supreme Delicious' on nine rootstocks in the 1980–81 NC-140 Cooperative Planting. Fruit Var. J. 45:213–219.

NC-140. 1991b. Performance of 'Starkspur Supreme Delicious' apple on 9 rootstocks over 10 years in the NC-140 Cooperative Planting. Fruit Var. J. 45:192–199.

Olien, W.C., W.C. Stiles, and R.C. McCrum. 1986. Field performance of *Malus sargenti* as a rootstock for four commercial apple varieties. Fruit Var. J. 40:140–143.

Perry, R.L. 1992. The relative susceptibility of rootstocks to fireblight. Proc. Mich. State Hort. Soc. 122:72–75.

Rom, C.R., R.C. Rom, W.R. Autio, D.C. Elfving, and R.A. Cline. 1991. Foliar nutrient content of 'Starkspur Supreme Delicious' on nine clonal apple rootstocks. Fruit Var. J. 45:252–263.

Schmidt, H. 1972a. Reaction of 25 apomictic apple rootstock selections to inoculation with a mixture of latent viruses. J. Hort. Sci. 47:151–157.

Schmidt, H. 1972b. The effect of 'latent' virus infections on the yield of maiden trees on 20 apomictic apple seedling rootstocks. J. Hort. Sci. 47:159–163.

Schmidt, H. 1982. Evaluation of rootstock characters in apomictic apple selections. Proc. 21st Intl. Hort. Congr. 1:111–119.

Watson, M.E. and R.A. Isaac. 1990. Analytical instruments for soil and plant analysis, p. 691–740. In: R.L. Westerman (ed.). Soil testing and plant analysis. Soil Sci. Soc. Amer., Madison, Wis.