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Performance of the NC-140 Cooperative Apple Rootstock Planting: I. Survival, Tree Size, Yield and Fruit Size[1]

NC-140[2]

Abstract

In 1984, trees of 'Starkspur Supreme Delicious' apple (*Malus x domestica* Borkh) on 15 rootstocks were planted at 31 sites in North America according to guidelines established for cooperative testing by the North Central Regional Cooperative Project (NC-140). Tree loss was greatest on P.22 (32%) and MAC.39 (21%). Trees on P.18, A.313, B.490, MAC.1 and M.4 had trunk cross-sectional areas (TCA) and yield efficiencies similar to seedling (SDL). P.1 produced trees similar in size, production and yield efficiency to M.7EMLA. C6 and M.26EMLA resulted in trees of similar size, yield and yield efficiency. MAC.39 and B.9 had similar TCA's, yield and yield efficiency, but trees on B.9 were shorter with smaller spread. Fruit size over 6 years from trees on P.22, M.4 and SDL was small, while fruit size tended to be large from trees on P.18, A.313 and C6.

Since apple rootstocks offer growers a means of increasing tree and orchard efficiency by 30-40%, researchers are challenged to identify rootstocks that meet the specific demands of each fruit-producing region. None of the commercially available rootstocks is adapted well to all North American fruit-producing regions. In the humid midwest, devastating tree losses have occurred due to fireblight infection of many dwarfing precocious rootstocks adaptable to intensive orchard systems (7, 15, 16). In other regions, cold winter temperatures are a limiting factor to tree survival and hardy rootstocks are desired (5, 6, 17, 19). The NC-140 committee, an international group of cooperating researchers, is organized to test new rootstock candidates over a wide range of sites. Previous reports (10, 11, 12, 13, 14) from this group have provided growers and researchers with information on performance of new apple rootstocks in a wide range of environments, thus shortening evaluation time.

The test plantings reported here were established in 1984 in 31 apple producing areas of North America to compare relatively untested selections from the Polish and Russian (Budagovsky) breeding programs. These breeding programs were established to provide rootstocks that would survive the severe cold of the European midcontinent and provide a range of tree sizes (4, 5, 18, 22). Also, included were two selections of the Michigan Apple Clone series (2), as well as C6, which was developed originally by Stark Brothers Nurseries and Orchards as a dwarfing interstem. These new selections were compared to apple seedling and several of the Malling rootstocks. A preliminary report on this planting was published previously (10).

Materials and Methods

Trees for the cooperative planting were propagated by TRECO, Inc., using virus-free 'Starkspur Supreme Delicious,' a spur-type strain, as the scion. Cooperators and the locations of their sites are listed in Table 1. Ten replicate trees of each of the 15 rootstocks listed in Table 2 were planted at

[1]Salaries and research support proved by state and federal funds appropriated to the Ohio Agricultural Research and Development Center, The Ohio State University.
[2]Author cooperators shown in Table 1. Appreciation is extended to TRECO, Inc., Woodburn, OR 97071 for propagating and donating trees for the planting and to the International Dwarf Fruit Tree Association for paying shipping expenses. Special thanks are extended to Bert Bishop, Ohio State University for performing statistical analyses of the data.

Table 1. Location and cooperators in the 1984 rootstock trial coordinated by NC-140.

Location		Cooperator	Planting Location
(AR)	Arkansas	Roy C. Rom, Curt R. Rom	Fayetteville
(BRC)	British Columbia	Harvey A. Quamme	Summerland, Canada
(CA)	California	Warren C. Micke	Kearney
(CO)	Colorado	Kenneth C. Yu, Alvan Gaus	Hotchkiss
(GA)	Georgia	Stephen C. Myers	Blairsville
(IL)	Illinois	Daniel B. Meador, Mosbah Kushad	Urbana
(IN)	Indiana	Richard Hayden	West Lafayette
(IA)	Iowa	Paul Domoto	Ames
(KS)	Kansas	Frank Morrison	Manhattan
(KY)	Kentucky	Gerald R. Brown	Princeton
(ME)	Maine	James R. Schupp	Monmouth
(MA)	Massachusetts	Wesley R. Autio	Belchertown
(MEX)	Mexico	Rafael A. Parra Quezada	Sierra de Chihuahua, Mexico
(MI)	Michigan	Ronald L. Perry	Clarkesville
(MN)	Minnesota	Emily E. Hoover	St. Paul
(MO)	Missouri	Michele R. Warmund	New Franklin
(NJ)	New Jersey	Edward F. Durner	Cream Ridge
(NY)	New York	James N. Cummins, Terrence Robinson	Geneva
(NC)	North Carolina	Eric Young	Fletcher
(NOS)	Nova Scotia	Charles G. Embree	Kentville, Canada
(OH)	Ohio	David C. Ferree	Wooster
(ONT)	Ontario	Donald C. Elfving, Ghassem Tehrani	Simcoe, Canada
(OR)	Oregon	Porter Lombard, Anita Azarenko	Corvallis
(PA)	Pennsylvania	Loren D. Tukey, Robert M. Crassweller	University Park
(TN)	Tennessee	Charles C. Mullins	Crossville
(TX)	Texas	Jody W. Worthington	Stephenville
(UT)	Utah	David R. Walker, J. Lamar Anderson	Farmington
(VA)	Virginia	John A. Barden	Blacksburg
(WA)	Washington	Bruce H. Barritt	Wenatchee
(WV)	West Virginia	Tara A. Baugher	Kearneysville
(WI)	Wisconsin	Teryl Roper	Sturgeon Bay

each site in a randomized complete block design. Ten pollenizer trees each of 'Macspur McIntosh' on M.26EMLA and 'Smoothee Golden Delicious' on M.26EMLA were included. Due to a shortage of trees on the following rootstocks (B.490, P.2, P.16, P.18, C6 and A.313), the following sites had a smaller trial: GA, KS, KY, ONT, MO, TN, NOS, NJ, TX, WV, MEX. Trees were spaced 3.5 m x 5.5 m with 5-7 cm of the rootstock exposed above the soil line. All trees were headed at 70 cm and trained to a free-standing central leader system with irrigation, herbicide and rate of nitrogen fertilizer applied according to local recommendations. Trees that leaned more than 45° were staked to prevent tree loss.

The following data were collected annually at each site and summarized at a central location (Ohio): survival, trunk circumference, tree height, tree spread, total yield/tree, average weight of 50 fruit. Each site also submitted monthly air and soil temperature averages and extremes, rainfall, and light values.

Results and Discussion

Total tree loss was greatest on P.22 and MAC.39 (Table 2). These rootstocks also had the greatest tree loss after the first 5 years (10) and lost an

Table 2. Mortality, growth, yield, precocity, and average fruit size of 'Starkspur Supreme Delicious' on 15 rootstocks across 30 sites in North America.

Rootstock	Tree loss (%)	1993 TCA (cm^2)	Relative* size (%)	1993 Tree size (cm)		Precocity cumulative yield (1984-89)		cumulative (1984-93) 10 years		Average fruit weight (1988-93) (g)
				height	spread	yield (kg)	efficiency (kg/cm^2)	yield (kg)	efficiency (kg/cm^2)	
Seedling SDL	5.0	152.4ab**	100	409b	370c	22.1bcd	.32	201.7bc	1.34f	160cd
P.18	5.3	164.0a	107	436a	412a	33.6abc	.43	280.9a	1.68def	181ab
A.313	5.3	155.8ab	102	436a	405a	27.9abc	.38	267.4ab	1.83def	181ab
B.490	0.1	147.0ab	96	434a	398ab	26.1abcd	.40	232.2abc	1.70def	180ab
MAC.1	3.5	142.4ab	93	404b	369c	25.1abcd	.43	219.5abc	1.61ef	172bc
M.4	7.1	138.7b	91	406b	384b	33.1abc	.56	262.9ab	1.95def	168bcd
M.7EMLA	4.2	102.7c	67	370c	341d	32.8abc	.73	215.7abc	2.30cde	179ab
P.1	5.3	98.3c	64	359c	334d	38.7a	.83	226.3abc	2.48cd	177ab
M.26EMLA	10.7	77.2d	50	332d	311e	34.9ab	.99	203.3bc	2.73bc	179ab
C6	14.6	63.4de	41	312e	297ef	34.2abc	1.16	182.1cd	3.14bc	190a
MAC.39	21.4	54.7ef	35	301e	284f	23.4bcd	.98	139.2de	2.76bc	178ab
B.9	12.8	41.1fg	27	254f	239g	28.1abc	1.36	118.1ef	3.34b	172bc
P.2	17.1	29.9g	19	216g	210h	21.0bcd	1.37	92.9efg	3.49b	176ab
P.16	18.5	20.1g	13	205g	176i	16.4cd	1,48	67.8fg	4.67a	177ab
P.22	32.1	20.1g	13	167h	135j	11.8d	1.37	41.9g	2.76bc	155d

*Relative size = TCA of rootstock ÷ TCA of seedling x 100.
**Means separated by Duncan's Multiple Range Test p = 0.5.

additional 15 and 11%, respectively, between 1988 and 1993. Rootstocks with greater TCA's than P.1 had minimal loss. P.18, A.313, B.490, MAC.1 and M.4 produced trees with similar TCA's to apple seedling (SDL). Tree height and spread of P.18, A.313 and B.490 were greater than SDL.

Among the 6 rootstocks similar in TCA to SDL trees on P.18 had higher cumulative yields than trees on SDL, but did not differ significantly from the other rootstocks in this size class. All were similarly efficient.

P.1 produced trees similar in size, productivity and efficiency to M.7-EMLA. A Polish study found trees of P.1 with 'Lobo,' 'Spartan,' and 'Empire' as scion cultivars were similar in size to trees on M.26 (5). In our study, M.26EMLA was significantly smaller than both P.1 and M.7EMLA with the spur-type 'Delicious' scion. Several studies (6, 17, 19) have shown that, among the widely planted Malling rootstocks, M.7 is the most injured by low winter temperatures. Trees on P.1 have been hardy and productive under test winters in central Europe (4, 18, 22) and in controlled freezing tests (6, 19).

The rootstock C6 produced trees similar in size, yield and efficiency to M.26EMLA, except they were shorter. Trees on MAC.39 and B.9 had similar TCA's, but trees on B.9 were not as tall and had a smaller spread than trees on MAC.39. Production and yield efficiency of trees on MAC.39 and B.9 were similar. Trees on P.2, P.16 and P.22 had similar TCA's, but trees on P.22 were shorter and had a smaller branch spread than trees on the other two rootstocks. Cumulative production and precocity per tree were similar among trees on these three rootstocks, but cumulative yield efficiency was highest for trees on P.16 followed by P.2 and P.22. Trees on P.2 and P.16 also had greater survival than trees on P.22. P.16 was reported to be less hardy than P.22 and P.2 (5, 19).

In addition to evaluating rootstock efficiency through yield/TCA yield per unit land area is often used to evaluate orchard efficiency. If yield per unit land area is calculated using

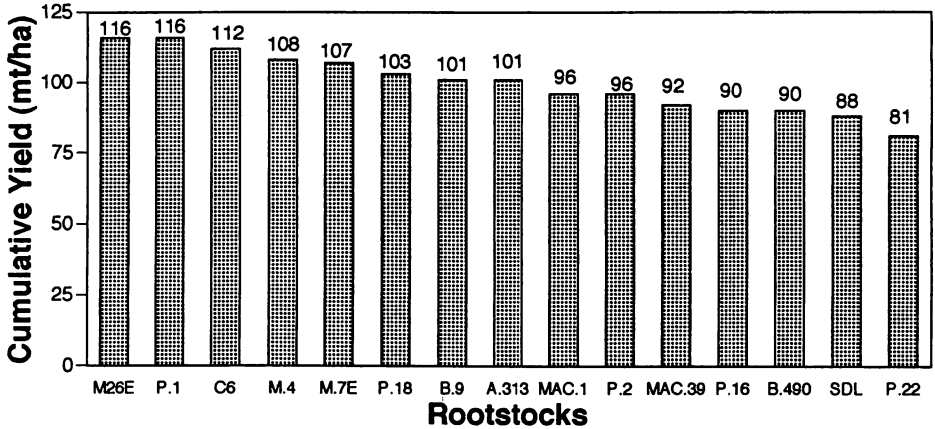

Figure 1. Potential cumulative yield/ha calculated using actual tree spread at 10 years and 2.5 m clear alley space.

actual tree spread at 10 years of age and allowing 2.5 m clear alley space, trees on M.26EMLA, P.1, C6, M.4 and M.7EMLA had the highest cumulative yields (Fig. 1). Tree numbers/ha ranged from 367 for P.18 to 1926 for P.22. It could be argued that 2.5 m clear is too much wasted space with trees on rootstocks of M.26 and smaller. If clear alley space is decreased to 2.0 m and yield/tree remains the same, cumulative yield/ha would be as follows: M.26EMLA (128.7 t), C6 (123.8 t), B.9 (113.5 t), P.2 (107.9 t), P.16 (102.6 t), MAC.39 (101.6 t) and P.22 (92.7 t). Reduction of clear alley space would require narrow wheel-base tractors and specialized equipment and the trees likely would be trained differently than the general central leader training used in this trial. Since it is known that planting trees closer, particularly in the row, decreases yield/tree (9, 20), production efficiency may be overestimated. However, at most sites many of the trees in this trial did not fill the 3.5 m in-row space allotted and crowding was minimal.

Fruit size averaged over the last 6 years of production tended to be small on trees of P.22, M.4 and SDL (Table 2). The three rootstocks that consistently produced in the largest average fruit size category were P.18, A.313, and C6. Most previous European studies did not evaluate fruit size (4, 5, 18, 22). Except for 1988 when the trees were young and producing their first significant crop, the difference between rootstocks producing the largest and smallest fruit size were consistent (Fig. 2A). Webster and Tobutt (21), in a study in England with 'Cox's Orange Pippin,' reported smaller fruit size from trees on P.22 than on P.16 or B.9, and relatively large fruit size from P.18. Average fruit size is not always related to tree size. For example, trees on SDL, which are large trees, had small fruit size; and P.16 and P.2 had relatively large fruit size, and produced small trees in this study. In a study in England, fruit size was small with trees size similar to the trees in this study (21). The fruit sizes presented here were not adjusted for crop load or analyzed with crop load as a covariant. However, trees on C6, which had some of the highest yields per unit of tree growth (efficiency) also had large fruit size (Fig. 2A & B). It also is noteworthy that trees on SDL had low cumulative yield and efficiency and also tended to have smaller fruit size compared to trees on P.18, A.313 and B.490, which produced trees of similar size.

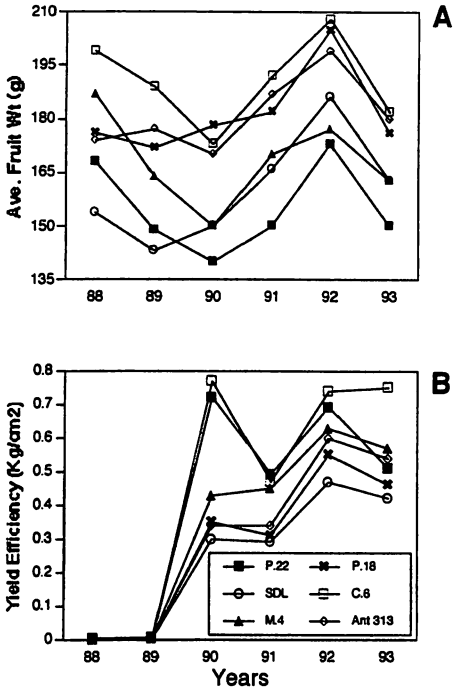

Figure 2. Average fruit weight and yield efficiency for 1988-93 of 'Starkspur Supreme Delicious' on the three rootstocks with the largest and smallest average fruit size.

Rootstocks in this trial produced a continuum of tree sizes from 2m in height (P.16 and P.22) to 4.4m in height (P.18 and A.313). Of the 5 rootstocks that were similar in TCA to SDL, P.18 had a higher cumulative yield and larger fruit size. Since other studies report that P.18 is hardy and resistant to collar rot (3, 19), it would be preferred if a seedling sized tree is desired.

Since M.7EMLA and P.1 were similar in all respects, P.1 could be an alternative in regions where lack of winter hardiness is a concern. Trees on M.26-EMLA and C6 were similar in size, production, efficiency and fruit size. Previous work has shown that both are very susceptible to fireblight (7, 8, 15, 16), so no clear advantage is evident for either rootstock.

Trees on MAC.39 and B.9 were similar in size, production, yield efficiency and fruit size. In other studies these rootstocks produced trees similar in size to M.9 (1, 8, 21) and although M.9 was not a control rootstock in this trial, the relative ranking would approximate M.9 tree size. Both rootstocks are reported to be similar to M.9 in susceptibility to fireblight (3, 15). B.9 has been shown to be significantly hardier than M.9 (5, 18, 19) and would be considered where M.9 has not been sufficiently hardy.

P.2, P.16 and P.22 produced very small trees with similar cumulative yields. Tree loss on P.22 was high and it produced consistently small sized fruit. Lack of staking could have played a major role in the poor performance of these dwarfing rootstocks.

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Performance of the NC-140 Cooperative Apple Rootstock Planting II: A 10-Year Summary of TCA, Yield and Yield Efficiency at 31 Sites

NC-140[1]

Abstract

In 1984 trees of 'Starkspur Supreme Delicious' apple (*Malus x domestica* Borkh) on 15 rootstocks were planted at 31 sites in North America according to guidelines established for cooperative testing by the North Central Regional Cooperative Project (NC-140). Six midwestern sites lost 20% or more of the trees over 10 years, while 13 sites had less than 10% loss. The following rootstocks had 60% or higher losses at one or more sites: MAC.39, P.22, M.4, M.26EMLA, P.2, P.16, P.18, C6. B.9 had the best survival of the dwarfing rootstocks in this study with no losses at 14 sites. Sites in KS, GA, IL, CA, VA, MO, NC, and MI had trees with 39 to 16% larger than average trunk cross-sectional area (TCA), while trees in TN, PA, and MEX were 40% smaller than the average of all sites. Averaged across rootstocks, sites with the greatest yield efficiency were MA, CA, OH, and BRC and those with lowest efficiency were KS, TN, MN, NY, AR and NC.

Evaluations of potential apple rootstock and interstem systems have been made independently by researchers at many locations. Lack of common genetic materials, spacings, and handling procedures have made comparison of the results from these independent studies difficult. Because of lack of information, growers have planted many scion/rootstock combinations at inappropriate spacings for their soils or that were poorly adapted to their area. Extension recommendations often vary widely from region to region with little understanding among professional horticulturists for the differences.

[1]Authors listed in Table 1, page 7, FVJ 50(1):1996.

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