ment of 650 hours (below 7°C). Time of bloom is approximately 4 days before 'Elberta' at Byron with large petaled, showy, light-pink blossoms which are self-fertile. Leaf glands are globose and trees are moderately vigorous but susceptible to bacterial spot [*Xanthomonas campestris* pv *pruni* (Smith) Dye]. Fruit are small to medium in size, round with a slight tip and semi-freestone when fully ripe. Flesh color is medium yellow with no red flecking. Fruit are firm but melting, medium in texture and with a good subacid flavor. Fruit have a nonprominent suture and fine short pubescence. 'Springcrest' has exhibited fewer split pits than most other early cultivars but some may occur when crops are light. In California, exterior color is very attractive, having a bright red blush on 90 percent of the surface over a yellow ground color. In the Southeast, 'Springcrest' fruit tend to have excessively dark red color unless trees are growing vigorously (Savage and Prince, 1972).

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Performance of 'Starkspur Supreme Delicious' Apple on 9 Rootstocks Over 10 Years in the NC-140 Cooperative Planting

NC-140[1]

Abstract

In 1980-81, trees of 'Starkspur Supreme Delicious' on 9 rootstocks were planted at 27 sites in the United States and Canada according to guidelines established for cooperative testing by NC-140. The greatest tree losses occurred with the rootstocks O.3 (38.9%) followed M.27 EMLA (27.7%), MAC.24 (26.1%), M.9 EMLA (24.4%) and M.9 (20.0%), with M.7 EMLA (3.3%) and OAR.1 (6.1%) having minimal losses. MAC.24 produced the largest trees, followed by OAR.1 and M.7 EMLA, with M.27 EMLA producing the smallest trees. Trees on M.9 EMLA, M.9 and MAC.9 did not differ in tree size. Trees on MAC.24 produced excessive suckers and those on MAC.9 produced an adventitious swelling at and below the soil line. Trees on MAC.24, OAR.1 and M.7 EMLA produced much less fruit/unit trunk cross-sectional area than the smaller trees. Calculating production potential per hectare using actual 10-year-old size, trees on MAC.9 had the greatest potential, followed by M.26 EMLA, O.3, M.7 EMLA, and M.9 EMLA, while trees on OAR.1 had the lowest potential. Comparison over 5 years showed a tendency for fruit on trees of M.27 EMLA and OAR.1 to have smaller average fruit size.

The margin between the production costs and fruit value has been getting progressively smaller, and growers have had to increase orchard efficiency to stay competitive. The most widely

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Cooperators shown in Table 1. Appreciation is extended to Oregon Rootstock, Inc., Woodburn, OR 97071 for propagating and donating trees for the planting and to the International Dwarf Fruit Tree Association for shipping expenses. Special thanks are extended to to Bert Bishop, Ohio State University for performing the statistical analyses of the data.

adapted method of increasing efficiency is to intensify plantings with smaller and more efficient trees, which depend on size-controlling rootstocks. The principle size-controlling apple rootstocks in commerce today were gathered and classified by the East Malling Research Station beginning in 1912 (10). Since that time, several apple frrtstock breeding and selection programs have been started and selections from those programs are beginning to be introduced (3, 10, 15).

Efforts in England to remove known viruses from commercially important Malling (M.) and Malling Merton (MM.) clones (2, 10) have resulted in clean strains identified by the acronym EMLA (4). Initial reports (2, 14, 16) indicate that M.9 EMLA may be as much as 50% more vigorous than the original M.9 with a portion of the differences attributed to clonal variation. Although M.9 has not been widely used in North America in the past, its use is increasing along with expanded use of other Malling stocks. Thus, it seemed imperative to evaluate the performance of the most widely used stocks with EMLA status across a wide array of sites.

The test plantings reported here.were established in 1980-81 in 27 apple producing areas of the United States and Canada to compare performance of a common scion on 9 rootstocks, either newly introduced or those with EMLA status. Performance during the first five years of these plantings was reported previously (13); this paper summarizes data from the last five years and draws conclusions based on rootstock performance.

Materials and Methods

Trees for the cooperative plantings were propagated by Oregon Rootstock, Inc., using virus-free 'Starkspur Supreme Delicious,' a spur-type strain, as the scion. The following rootstocks were included in the trial: O.3, M.7 EMLA, M.9 EMLA, M.26 EMLA M.27 EMLA, M.9, MAC.9, MAC.24, and OAR.1. Rootstocks designated EMLA were derived from rootstocks of EMLA status, free of known viruses. Ten pollenizer trees each of 'Macspur McIntosh'/M.26 and 'Starkspur Golden Delicious'/M.26 were also included. Because of limited amounts of some rootstocks, five replications were planted in 1980 and five were planted in 1981. The following locations received no trees in 1980 and 10 replications in 1981: MO, UT, NC, MT, SC, TN, and CO. Cooperators and locations are shown in Table 1. Trees were planted as individually randomized

Table 1. Cooperators and site locations in the NC-140 apple rootstock trial established in 1980-81.

State or Province	Cooperator	Planting location
AR	Curt R. Rom	Fayetteville
CA	Warren C. Micke/ Ronald Tyler	Watsonville
CO	Matthew K. Rogoyski	Hotchkiss
GA	Stephen C. Myers	Blairsville
IL	Daniel B. Meador	Urbana
IN	Richard Hayden	West Lafayette
IA	Paul Domoto	Ames
KS	Frank Morrison	Manhattan
KY	Gerald R. Brown	Princeton
MA	Wesley R. Autio	Belchertown
MI	Ronald L. Perry	Clarksville
MN	Emily E. Hoover	St. Paul
MO	Michele R. Warmund	Columbia
MT	Nancy W. Callan	Corvallis
NC	Eric Young	Raleigh
NY	James N. Cummins	Geneva
OH	David C. Ferree	Wooster
OR	Porter Lombard/ Anita Miller	Corvallis
ONT	Donald C. Elfving	Simcoe
PA	Loren D. Tukey	University Park
QUE	Raymond L. Granger	St. Jean
SC	Donald C. Coston	Clemson
TN	Charles A. Mullins	Crossville
UT	David R. Walker	Farmington
VA	John A. Barden	Blacksburg
WA	Bruce H. Barritt	Wenatchee
WI	Elden J. Stang	Sturgeon Bay

blocks at each site. Planting plans were supplied by NC-140 and trees were spaced 3.5 x 5.5 m. The experimental design was a randomized complete block with 10 replications. Care was taken to ensure that 5-7 cm of rootstock remained above the final soil line and all trees were headed at 70 cm. Trees were trained to a central leader system with irrigation, herbicide and rate of urea fertilizer applied according to local recommendations. Since anchorage was unknown, half of the replications in each planting were not supported while the other half, which were planted in 1981, were supported by a post at each tree and tied at 1 m.

The following data were collected annually and summarized at a central location: trunk circumference, number of root suckers, tree height, tree spread, total yield/tree, and average weight of 50 fruit. Each site submitted monthly air and soil temperature extremes, rainfall, and light values.

Results and Discussion

Since insufficient tree numbers were available in 1980, each site received five replications that were not supported, with an additional five replications planted in 1981 that were supported by stakes. In the early years, trees planted in 1980 and unstaked were generally larger and had slightly higher yields (data not shown). After 10 years, only unstaked trees on MAC.24 planted in 1980 were significantly larger than trees on MAC.24 planted a year later and staked (Table 2.). Cumulative yield/tree of earlier planted, unstaked trees was higher on M.7 EMLA, MAC.24 and OAR.1 with no difference among other rootstocks. Yield efficiency (Kg fruit per cm^2 trunk cross-sectional areas [TCA]) was also higher on trees on MAC.24 and OAR.1 that were early planted and unstaked compared to trees on these rootstocks that were subsequently planted and staked. It is interesting that with the exception of M.9 EMLA the three rootstocks still showing yield differences after 10 years are generally accepted as free-standing, were the largest trees and in the case of MAC.24 and OAR.1 the latest to begin bearing. Support is generally recommended for the smaller rootstocks in this trial and staking was likely one factor in overcoming the disadvantage of planting a year later. Staking and year of planting did not alter the relative ranking of rootstocks when comparing TCA, yield, or yield efficiency and thus, subsequent data will present the composite data from all trees staked and unstaked.

As previously described (13), plantings in NY, MT, SC. and MN were removed because of excessive tree loss. A summary of losses from other sites (Table 3) shows that the greatest losses occurred with O.3 (38.9%) followed by M.27 EMLA (27.7%), MAC.24 (26.1%), M.9 EMLA (24.4%) and M.9 (10.0%). Only trees on M.7 EMLA and OAR.1 had less than 10% loss over the 10 years of this study. The rootstocks M.9, MAC.24, and O.3 had higher losses in the last five years than the other rootstocks. Greater tree loss occurred on trees planted in 1981 than those planted in 1980 (13). Most of this loss could be attributed to poor tree quality, sparse root systems and rather poor growth made in the nursery.

MAC.24 produced the largest trees in this trial having nearly 84% larger trunk area, and being 23% taller and having 34% greater spread than trees on OAR.1 and M.7 EMLA which were next largest (Table 3). Trees on M.26 EMLA were significantly larger than trees on O.3, M.9 EMLA, M.9 and MAC.9 which did not differ in TCA. Of the trees in this group, M.9 and MAC.9 had less spread and tended to be shorter than trees on O.3 and M.9 EMLA. Trees on M.9 EMLA were 30% larger than trees on M.9, but did not differ significantly from M.9 due to the variation among sites. The difference between M.9 and M.9 EMLA

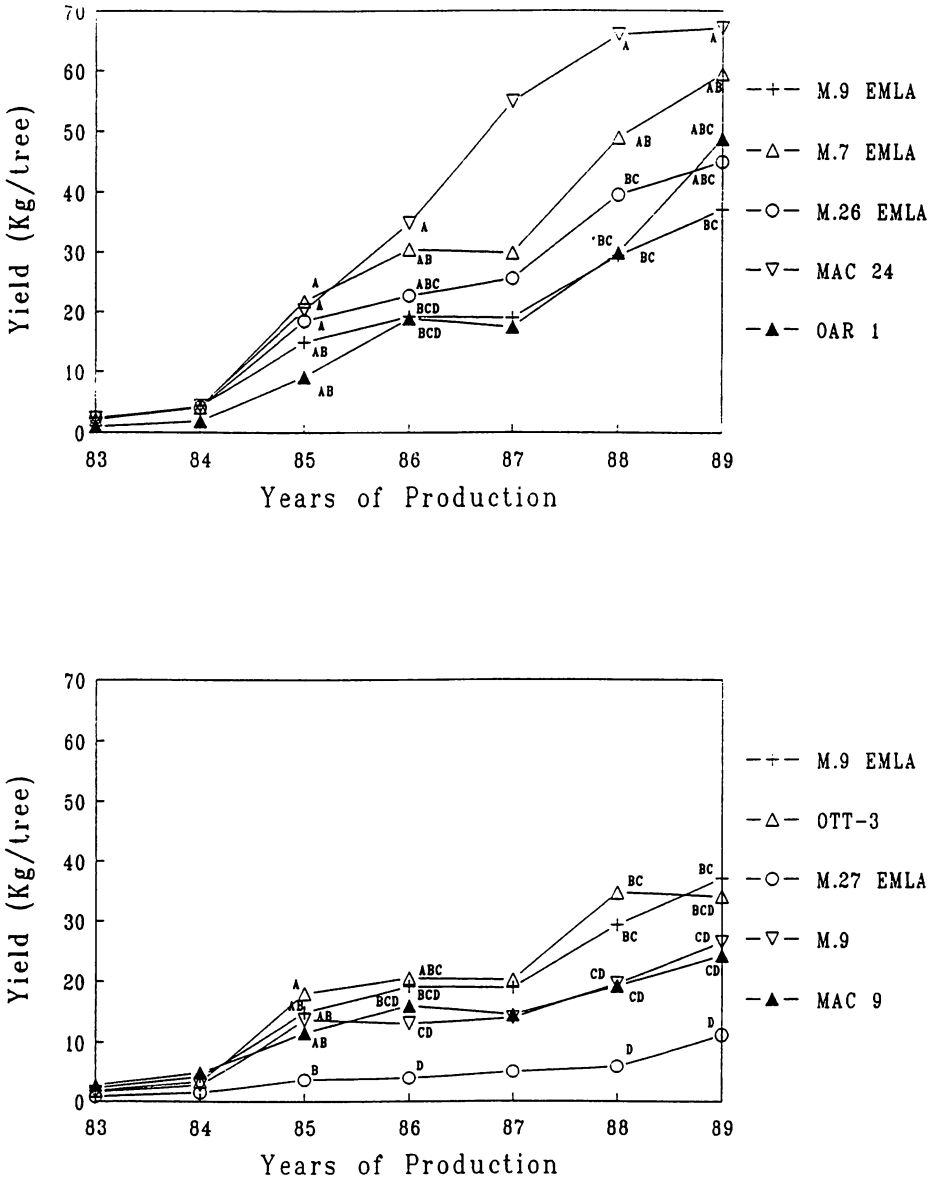

Figure 1. Yearly production per tree of 'Starkspur Supreme Delicious' on 9 rootstocks in the NC-140 trial planted in 1980-81.

Table 2. Influence of staking and year of planting on tree size, cumulative yield and yield efficiency of 'Starkspur Supreme Delicious' on 9 rootstocks in the NC-140 uniform rootstock planting (through 1989).[z,y,x]

	Trunk cross sectional area (cm^2)		Year of planting cumulative effect	Yield/tree (kg)			Cumulative yield efficiency (kg/cm^2)		
Rootstock	Not staked	Staked	F-significance staked[y]	Not staked	Staked	F-significance staked	Not staked	Staked	F-significance staked
O.3	46.1d	41.4c	NS	144.7bc	115.9abc	NS	3.29a	3.07abc	NS
M.7 EMLA	99.8b	83.4b	NS	226.0ab	130.1ab	**	2.36abc	1.73cde	NS
M.9 EMLA	43.3d	38.7c	NS	145.7bc	116.4abc	**	3.59a	3.32ab	NS
M.26 EMLA	68.5c	71.3b	NS	167.6bc	146.7a	NS	2.74ab	2.29bcd	NS
M.27 EMLA	10.7e	9.6d	NS	33.7d	40.0e	NS	3.44a	4.24a	NS
M.9	31.0de	27.8c	NS	99.2cd	80.7cde	NS	3.46a	3.19abc	NS
MAC.9	28.8de	27.0c	NS	107.0cd	93.3cd	NS	3.73a	3.56ab	NS
MAC.24	185.1a	137.1a	*	291.6a	87.2bcd	*	1.37c	.65e	*
OAR.1	100.5b	85.6b	NS	144.7bc	68.9de	*	1.89bc	.94de	*

[z]Mean separation within columns by Duncan's New Multiple Range Test ($p = 0.05$).
[y]Non-staked trees were planted in 1980 and staked trees in 1981, thus staking and year of planting are confounded.
[x]F-significance within rootstock—NS. *, **: Nonsignificant, * = 5%; ** = 1% levels respectively.

was less than the 50% reported in other studies (2, 14, 16), and may have been due to the spur type growth habit of the scion used in this study. Trees on M.27 EMLA were smallest by all tree size criteria. Barritt (1) suggests that 400-1200 trees/acre (988-2964 trees/ha) are required for modern efficient intensive orchards. If actual tree spread after 10 growing seasons and a fixed between-row clearance of 2.5 m is used to calculate tree densities, it is clear that M.9, MAC.9 and M.27 EMLA naturally fit this required optimum density range with spur 'Delicious' as the cultivar. However, significant growth control through training and pruning would be required for rootstocks such as O.3, M.9 EMLA and M.26 EMLA to be appropriate for intensive production systems. It must also be recognized that tree to tree competition was very minimal in these plantings. If competition had existed, as it would in modern intensive orchards, tree size would be reduced and the three rootstocks mentioned above may adjust quite well. As reported previously (13), suckering with MAC.24 was a serious problem with some sites reporting more than 200 suckers per tree. While suckers associated with other rootstocks were concentrated in close proximity to the trunk, suckers on MAC.24 were widely dispersed under the drip line of the tree. Although trees on MAC.9 did not sucker profusely, they did develop adventitious swellings at and below the soil line. These swellings were not visible when the trees were five-years-old (13), but were first noticed after 7 years and were widely reported (see paper on abnormalities) when the study was terminated at 10 years of age.

Generally, cumulative yield/tree followed tree size with larger trees having higher yields than smaller trees (Table

Table 3. Tree loss, tree size and cumulative yield of 'Starkspur Supreme Delicious' apple trees on 9 rootstocks in the NC-140 uniform rootstock planting (through 1989).

Rootstock	Total tree loss (%)	Trunk area (cm^2)	Relative tree size (%)	Tree size (cm) Height	Tree size (cm) Spread	Cumulative yield Per tree kg/tree	Cumulative yield Effic. (kg/cm^2)	Root suckers/ tree (1989)	Potential cumulative yield/ha[y] Trees/ ha	Potential cumulative yield/ha[y] Tons/ ha
O.3	38.9	44.4d	25.7	258d	268cd	136.2bc	3.28ab	3.6b	720	98.0
M.7 EMLA	3.3	91.3b	52.9	369b	332b	186.5ab	2.16bc	10.6b	512	96.4
M.9 EMLA	24.4	40.7d	23.6	251d	253d	122.7bcd	3.28ab	0.9b	786	96.4
M.26 EMLA	14.4	67.5c	38.1	313c	286c	152.4abc	2.53ab	0.9b	652	99.3
M.27 EMLA	27.7	10.3e	5.9	140f	111f	31.9d	3.39a	0.2b	2500	79.7
M.9	20.0	28.7de	16.6	223de	218e	85.5cd	3.25ab	2.8b	980	83.8
MAC.9	18.3	27.6de	16.0	200e	198e	95.8bcd	3.43a	1.8b	1127	107.9
MAC.24	26.1	172.4a[y]	100.0	434a	403a	241.0a	1.15c	36.8a	380	91.6
OAR.1	6.1	93.6b	54.3	354b	300c	119.1bcd	1.37c	6.4b	606	72.1

[z]Mean separation within columns by Duncan's New Multiple Range Test ($p = 0.05$).
[y]Potential yield/ha calculated using actual tree spread as in-row spacing and in-row spacing plus 2.5 m as space between rows multiplied by the cumulative yield/tree.

3). However, when production efficiency is evaluated using yield per unit TCA, the large trees on MAC.24, OAR.1 and M.7 EMLA were the least efficient trees. If actual tree spread is used to calculate an appropriate spacing and potential yield/ha, trees on MAC.9 clearly have the greatest potential for high yields followed closely by M.26 EMLA, O.3, M.7 EMLA and M.9 EMLA. However, it should be noted that trees size on MAC.9 in these plantings tended to be small, partially due to heavy early crops. The current suggestion to thin early crops on MAC.9 to prevent the senescent and spur-bound condition will likely result in larger trees. Trees on OAR.1 clearly had the lowest yield potential per ha. Single-row plantings of small trees increase the proportion of orchard floor devoted to between-row spacing in smaller trees. If this approach is used in estimating orchard performance, then the smallest trees in the trial, MAC.9 and M.27 EMLA, display the greatest potential yield per hectare. It is recognized that these calculations tend to overestimate production potential because tree to tree competition was very minimal in this planting. When tree to tree competition exists, tree size and yield per tree are also reduced, a normal condition expected in an intensive planting. Also, these calculations do not take into account the impact of tree mortality on potential production.

The average annual yield/tree over the production years (1983-89) shows that all rootstocks followed generally the same pattern of increasing production with age (Fig. 1). Trees on MAC.24 had nearly an incremental increase in yield as trees increased in size, while trees on M.27 EMLA had only a small increment, reflecting a small change in canopy volume as the trees aged. When the change from year 5 to year 10 is compared, M.27 EMLA did not change in tree height but increased 28% in TCA, while trees on MAC.24 increased 21% in height and 63% in TCA. Trees on M.7 EMLA tended to have higher yields/tree than trees on OAR.1 in each year of the study (Fig. 1) and also higher cumulative yield and yield efficiency (Table 3), although differences were not statistically significant. Trees on these two rootstocks were nearly identical in size, although trees on OAR.1 had a more upright growth habit.

A yearly evaluation of fruit size revealed no significant effect on average fruit size in any one year (Table

Table 4. Influence of 9 rootstocks on the NC-140 uniform rootstock planting on average fruit weight (grams/fruit) over 5 years of 'Starkspur Supreme Delicious.'

	Fruit weight (g/fruit)					
Rootstock	1985	1986	1987	1988	1989	Average
MAC.24	218	158	224	107	191	195
OAR.1	211	137	194	167	168	175
M.7 EMLA	241	168	225	190	186	202
M.26 EMLA	228	170	236	183	192	202
O.3	218	162	215	188	176	191
M.9 EMLA	232	170	236	183	192	202
M.9	227	150	217	169	182	189
MAC.9	215	152	208	165	177	183
M.27 EMLA	203	134	191	146	153	165
LSD	NS	NS	NS	NS	NS	

4). It should be noted, however, that fruit from trees on M.27 EMLA and OAR.1 had the smallest average size in each of the five years. Recent reports (5, 6, 7, 8) indicate that fruit from mature trees on OAR.1 had improved color, soluble solids, firmness, lower levels of mineral content and delayed ethylene development compared to fruit from seedling, M.1, MM.106, M.7 and M.26. However, fruit from trees on OAR.1 were also 10% smaller than on the other rootstocks. Cumulative yields (7) over a 6-year period showed that trees on OAR.1 produced 22% more fruit than trees on seedling rootstocks with the other rootstocks increasing fruit production as follows relative to seedling: M.26, 37%; M.1, 39%; M.7, 40%; MM.106, 49%. Thus, long-term production from OAR.1 was not as high as from other commercially accepted rootstocks.

Previous trials (11, 17) have also reported small fruit size on trees of M.27 rootstock. However, Tukey (18) reported that fruit size of several cultivars on M.27 was equal or larger than fruit size on M.9, but stated smaller size fruit can occur with M.27. When M.27 was used as an interstem, a tendency existed for reduced fruit size in some trials (19) with little effect in others (9, 12).

In summary, MAC.24 would not be recommended for most sites because of its large tree size, lack of precocity, and severe suckering problem. OAR.1 would not be recommended because of its lack of precocity. Trees on M.7 EMLA performed best of the larger trees in this study and would continue to be recommended for medium density orchards. Although a direct comparison was not made in this trial, trees on M.7 EMLA appeared to perform similarly to M.7, and no difference in planting distance or management would be required.

Of the more dwarfing rootstocks, the significant tree loss that occurred with O.3 was a concern. This loss was likely due to the poorly developed root system on trees at planting. As propagation techniques improve for O.3, better initial root systems and tree survival would be expected.

Of the remaining rootstocks, M.26 EMLA produced the largest trees, survived well, was precocious and provided a rootstock for intensive orchards where some additional vigor would be needed. M.9 EMLA, M.9 and MAC.9 had rather high tree losses, which might have been reduced if all trees had been supported from planting. There was very little difference in tree size or performance of M.9 and MAC.9; however, the spur type scion in this study became more spur bound on MAC.9. The adventitious swelling at and below the soil line on MAC.9 is a concern, although to date the effects are unknown. M.27 EMLA resulted in a very stunted tree when combined with a spur-type scion. The tendency for small fruit was also a concern and M.27 EMLA may be limited to more vigorous cultivars on strong soils.

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New Quince Hybrid Rootstocks for Pears

In their influence on scion vigour, 196-8 and 193-2 were similar to Quince A. The following were intermediate between Quince A and Quince C: 42-1, 42-3, 190-1. Selection 193-16 was similar in size, nursery performance, precocity to Quince C and was the most promising clone. Selection 193-16 was outstanding for the production of large, uniformly sized fruits.

From Browning and Watkins, 1991. *J. Hort. Sci.* 66:35-42.