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Early Field Performance of Several Self-rooted, Micropropagated Apple Cultivars vs. Trees on Seedling or M. 7a Rootstocks[1, 2]

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Abstract

Tree size and yield of several self-rooted (from micropropagation) apple cultivars planted in 1984 were compared in 1987 and 1988 with trees on seedling and M. 7a stocks. In both years, trees were generally smallest on M. 7a. 'Jonathan,' 'Rome,' and 'Spartan' were usually largest when self-rooted; 'Golden Delicious' and 'McIntosh' tended to be largest on seedling roots. In 1987, yield of all cultivars was generally highest on M. 7a, with few differences between self-rooted trees and trees on seedling. By 1988, rootstock had no significant effect on yield. Except for 'Spartan' and 'Delicious,' yield efficiency in 1987 was significantly higher on M. 7a than on the other roots. By 1988, yield efficiencies were 0.21, 0.31, and 0.36 kg cm^{-2} for self-rooted, seedlings, and M. 7a, respectively, but the differences were not significant. Nearly all trees leaned in response to a prevailing westerly wind, with trees on seedling tending to be more upright (16° from vertical) than micropropagated trees (21°) or those on M. 7a (23°). There was, however, a cultivar/rootstock interaction for anchorage. The most poorly anchored combination was 'Spartan'/M. 7a (39°) while 'Spartan'/sdlg and 'McIntosh'/M. 7a were among the best anchored combinations (13.5° and 15.0°, respectively).

Introduction

In an April, 1980, national conference on tissue culture propagation of fruit plants, Faust and Fogle (3) were optimistic about the future of micropropagated fruit trees. Among their predictions were, a) trees will be grown on their own roots, and many will probably be semi-dwarf when self-rooted, b) micropropagated trees will be free of known latent viruses, and c) grafting will be necessary only "where the characteristics of the rootstock are absolutely essential." Faust and Fogle (3) also claim that micropropagated trees, which come from forced buds, will be vegetative early in life, will produce somewhat larger trees, and will require more time between planting and production than grafted trees. Also, 20-25 years may elapse before the effects of tissue culture propagation on tree fruit production practices will be known.

Presently, it appears that peaches are the only tree fruit where own-rooted trees are commercially significant, and these trees generally appear to be propagated by cuttings because micropropagation of peach scion cultivars has generally been only moderately successful (2). We appear to be very little closer than in 1980 (3) to the use of species other than peach on their own roots, but some success has been reported with apple (5, 9, 10, 11), although results varied with the cultivar. Later bearing has been reported for micropropagated apple, plum, and sour cherry (1, 7, 8), and a loss of the spur habit occurred in apple (7). Where negative results have been reported for micropropagated trees, they may have resulted from use of smaller trees in comparison to grafted trees (9, 10). The results have also been highly cultivar dependent (5, 9, 10).

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[2]Micropropagated trees were provided by Dr. Richard H. Zimmerman, USDA-ARS, Beltsville, MD. Remaining trees were provided by Van Well, C and O, and Columbia Basin nurseries.

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In spite of the uncertain results observed thus far for micropropagated fruit trees, the potential suggested earlier by Faust and Fogle (3) still exists. The work reported in this paper is a comparison of tree size, yield, and yield efficiency of several 4-year-old apple cultivars either budded on seedling or M. 7a rootstocks or produced on their own roots from micropropagation.

Materials and Methods

A planting of 'Golden Delicious,' 'Jonathan,' 'McIntosh,' 'Rome,' 'Royal Red Delicious,' and 'Spartan' was made in April 1984 at the Washington State University Royal Slope Research Unit near Othello, Washington. Trees were self-rooted from micropropagation or were budded on seedling or M. 7a rootstocks. Micropropagated 'Delicious,' 'Golden Delicious' and spur 'McIntosh' were grown for 1 yr in the nursery while all others had grown 2 yrs before orchard planting. The 'McIntosh' from micropropagation was 'Paladino Spur McIntosh' while those on seedling and M. 7a were 'Morspur McIntosh.' Trees of 'Royal Red Delicious'/seedling were unavailable for planting until 1985. Initial trunk diameter of the 2-yr trees was larger than 1-year trees. Overall, trees on seedling, on M. 7a, and on their own roots averaged 16.8 mm, 15.7 mm, and 14.9 mm trunk dia., respectively, at planting.

The block was planted in a triple-row configuration; trees were spaced 3.7 m × 3.7 m in a diamond arrangement with 7.3 m between sets of triple rows. The experiment was established as a completely randomized design with four 3-tree replicates. The trees were well brancehd at planting (except for 'Delicious' on seedling and M. 7a stocks). The leaders were pruned to a uniform height, and side branch length was reduced by one third. Branches with poor angles or spacing were removed, leaving 4 to 6 laterals per tree. Unbranched 'Delicious' trees were pruned to 1 m high. Overhead sprinkler irrigation was used, and trees were fertilized uniformly. 'Alta' fescue grass was seeded between rows, and a 1.2 m wide weed-free strip was maintained under-tree with paraquat. Negligible flowering occurred in 1985 and 1986.

Data collected included trunk diameter, fruit yields (fruit number per tree in 1987 and kg per plot in 1988), and tree anchorage as reflected by the degrees from vertical that trunks leaned away from a prevailing westerly wind.

Data for both 1987 and 1988 were analyzed as a 3 (roots) × 6 (cultivars) factorial experiment in a completely randomized design. In 1987, individual trees were the experimental units. However, 1988 was the first year of commercial harvest, and the experimental units therefore became the 3-tree plots. Unequal sample sizes which resulted from rodent damage and other causes were accounted for by using least squares means (4). Data from plots in which one or two of the three trees had died were weighted by a factor of 3·(number of trees in the plot)$^{-1}$. Because of differences in initial tree size, data were subjected to analysis of covariance, with initial tree size (stem cross-sectional area) as the covariate, in order to remove initial size as an influence on tree performance.

Results

Tree size

Initial tree caliper: Initial tree size and nursery history of our trees varied. Diameter of own-rooted 'Jonathan' was larger at planting than most other trees, and this tendency has persisted (Fig. 1, 2). Own-rooted 'Rome' and 'Rome'/M. 7a were similar in diameter at planting, but own-rooted 'Rome' was clearly the largest of the 'Rome' trees in 1988 (Fig. 2). At planting, own-rooted 'Golden Delicious' and 'McIntosh' were the smallest of their respective cultivars (trees on seedling were largest), but in 1988, own-rooted trees were larger than trees on M. 7a and were not significantly smaller than trees on seedling (Fig. 2). Own-rooted 'Spartan' and 'Spartan'/seedling were similar at planting, but own-rooted 'Spartan' was larger than seedling in 1988. 'Delicious'/seedling was largest of the 'Delicious' trees at planting (1 year late), but has been surpassed in size by trees on their own roots (Fig. 2).

The initial differences in tree size, in general, had a small but diminishing effect (1988 vs. 1987) on trunk cross-sectional area, and had no significant effect on yield and yield efficiency.

Trunk cross-sectional area (1987): Tree size of each cultivar depended upon rootstock ($P < 0.0001$, Fig. 1). 'Jonathan,' 'Rome,' 'Spartan,' and 'Delicious' were largest on their own roots, whereas 'Golden Delicious' and 'McIntosh' were largest on seedling and their own roots. 'Jonathan,' 'Golden Delicious,' and 'McIntosh' were smallest on M. 7a (Fig. 1). Among scions within rootstocks, 'Jonathan' and 'Rome' were the largest self-rooted trees; 'Jonathan' and 'McIntosh' were the largest trees on seedling rootstocks; and 'Rome,' 'McIntosh,' and 'Spartan' ranked the largest on M. 7a (Fig. 1).

Trunk cross-sectional area (1988): As in 1987, tree size was affected by an interaction between scion cultivar and rootstock ($P < 0.0001$). 'Rome,' 'Spartan,' and 'Delicious' all had the largest trees on their own roots (Fig. 2). With 'Jonathan,' 'Golden Delicious,' and 'McIntosh,' trees on M. 7a were significantly smaller than those on the other two rootstocks. Among scions

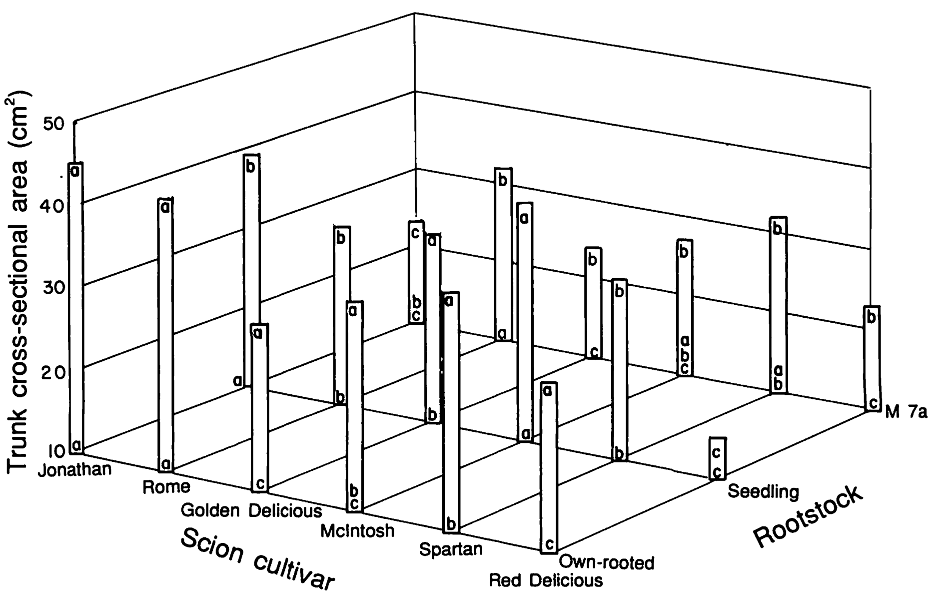

Figure 1. Trunk cross-sectional area in 1987 of several micropropagated apple cultivars and those on seedling and M. 7a roots planted in 1984. Letters at the top of bars determine differences among rootstocks within scions and those at the base determine differences among scions within rootstocks ($P \leq 0.05$).

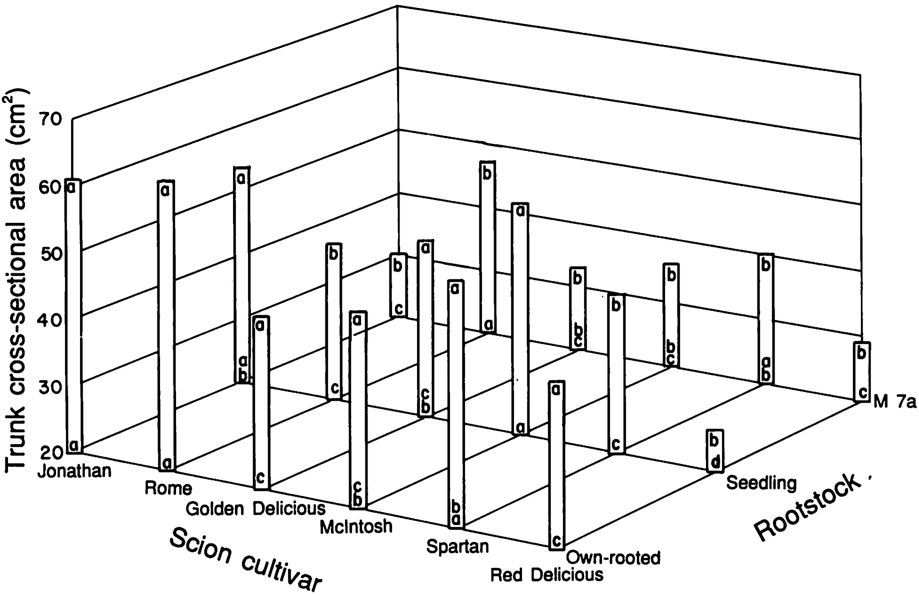

Figure 2. Trunk cross-sectional area in 1988 of several micropropagated apple cultivars and those on seedling and M. 7a roots planted in 1984. Letters at the top of bars determine differences among rootstocks within scions and those at the base determine differences among scions within rootstocks ($P \leq 0.05$).

within rootstocks, the largest self-rooted trees were 'Jonathan' and 'Rome' (Fig. 2). On seedling rootstock, no scion cultivars were clearly the largest. Of all trees on M. 7a roots, 'Rome' produced the largest trees (Fig. 2).

Yield

1987: A significant interaction occurred between cultivar and rootstock ($P < 0.001$) (Fig. 3). M. 7a was clearly the most productive rootstock. Yields on seedling stocks and self-rooted trees were usually similar. On M. 7a, 'Rome' produced significantly more fruit than the other own-rooted cultivars, while 'Delicious' and 'Spartan' produced the least. There was relatively little cultivar effect on production when seedling stock was used. 'Jonathan' on its own roots produced significantly more fruit than the other cultivars (Fig. 3).

1988: Analysis of variance indicated that yield was not affected by a significant interaction between scion and rootstock. Furthermore, there was no significant effect of rootstock on yield in 1988. Among scion cultivars, however, yield of 'Delicious' was significantly lower than all other cultivars except 'Golden Delicious' (Table 1), possibly partly because 'Delicious' trees on seedling roots were 1 year younger than other trees.

Yield efficiency

1987: With yield efficiency, there was a significant interaction ($P < 0.0001$) between cultivar and rootstock (Fig. 4). 'Jonathan,' 'Rome,' 'Golden Delicious,' and 'McIntosh' all had significantly higher yield efficiency on M. 7a than on the other rootstocks. No cultivar showed a significant difference in yield efficiency between seedling

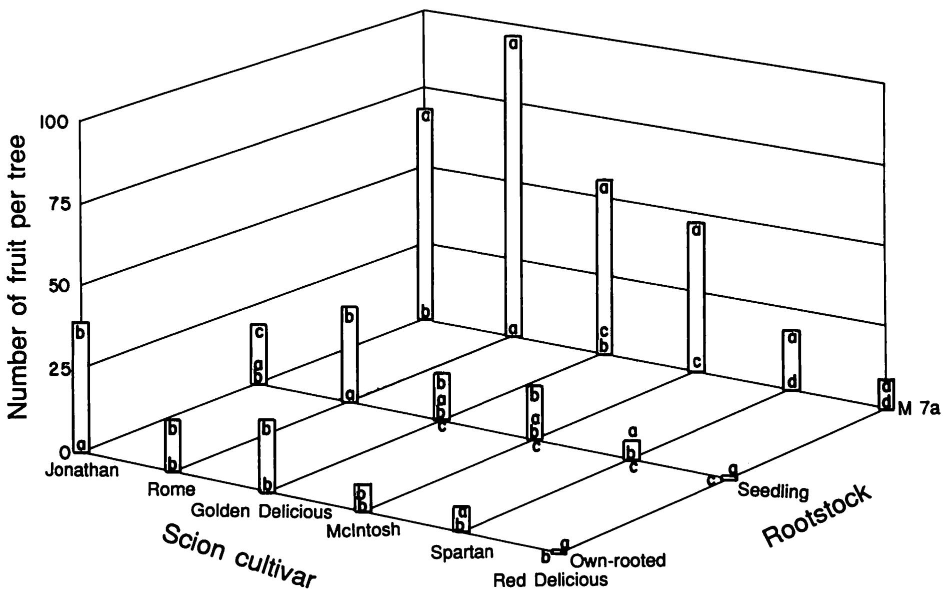

Figure 3. Yield (number of fruit per tree) in 1987 of several micropropagated apple cultivars and those on seedling and M. 7a roots planted in 1984. Letters at the top of bars determine differences among rootstocks within scions and those at the base determine differences among scions within rootstocks ($P \leq 0.05$).

and self-rooted stocks. Differences among cultivars within rootstocks were small, except on M. 7a, which provided significantly higher yield efficiency for 'Jonathan' and 'Rome' than for 'McIntosh,' 'Spartan,' and 'Delicious' (Fig. 4).

1988: Analysis of variance showed no significant interaction between scion and rootstock regarding yield efficiency, nor was there a significant effect of either scion or rootstock (Table 1). There was, however, a trend in yield efficiency related to rootstock, with own-rooted trees tending to be least efficient.

Anchorage/leaning

There was a significant interaction between scion and rootstock with respect to leaning. Of the 18 scion/rootstock combinations tested, however, the highest-ranking 12 could not be

Table 1. Yield and yield efficiency in 1988 of several apple cultivars planted in 1984 and growing either on their own roots (by micropropagation) or grafted onto seedling or M. 7a rootstocks.

Cultivar	Yield ($kg \cdot tree^{-1}$)	Yield efficiency ($kg \cdot cm^{-2}$)
Scion		
'Golden Delicious'	11.7 ab[z]	0.31 a
'Jonathan'	17.8 a	0.38 a
'McIntosh'	13.0 a	0.32 a
'Delicious'	5.3 b	0.19 a
'Rome'	12.6 a	0.26 a
'Spartan'	13.9 a	0.31 a
Rootstock		
Own-rooted	11.0 a	0.21 a
Seedling	13.2 a	0.31 a
M. 7a	13.0 a	0.36 a

[z]Means within columns and within either scions or rootstocks and followed by the same letter are not significantly different ($P \leq 0.05$).

Table 2. Anchorage/leaning (degrees from vertical) of apple trees (planted in 1984) as influenced by scion/rootstock combination (1989).

Treatment group	Leaning (°)
Rome/Seedling	13.4 a
Spartan/Seedling	13.5 a
Golden Delicious/Seedling	13.9 a
McIntosh/M. 7a	15.0 ab
Jonathan/Seedling	15.5 ab
Golden Delicious/M. 7a	15.9 ab
Spartan/Own	16.5 ab
Rome/Own	17.2 ab
Jonathan/M. 7a	17.3 ab
McIntosh/Seedling	17.3 ab
McIntosh/Own	17.5 ab
Jonathan/Own	19.3 abc
Royal Red Delicious/Seedling*	20.8 bc
Rome/M. 7a	25.1 cd
Royal Red Delicious/Own	25.7 cd
Royal Red Delicious/M. 7a	27.89 cd
Golden Delicious/Own	29.1 d
Spartan/M. 7a	39.4 e
Mean	19.3

^{z}Means within treatment group and followed by the same letter are not significantly different ($P \leq 0.05$).
*'Royal Red Delicious' on seedling rootstock was planted in 1985.

differentiated on the basis of the statistical analysis (Table 2). 'Delicious,' regardless of rootstock, ranked among the 6 most poorly anchored scion/rootstock combinations. 'Spartan'/M. 7a leaned significantly more than all other combinations (Table 2).

Discussion

Our results with micropropagated apple trees were similar in several respects to the results of others. The responses observed varied with the scion cultivar, as reported by Gyuro, et al. (5), Webster, et al. (9) and Zimmerman (10, 11). Even though micropropagation may have potential for producing trees at a much lower cost than budded trees (11), they may not fulfill the current need for smaller than standard sized trees. Our conclusions regarding tree size agree with what seems to be a general consensus regarding a need to control tree size and induce early flowering and fruiting if micropropagated trees are to be of use (12). At this early stage in the experiment, our trees on their own roots are equivalent to or larger (trunk cross-sectional area) than trees on seedling, as reported by Zimmerman (11), even though some own-rooted trees were initially smaller than seedling. At planting time, own-rooted 'Rome' and 'Jonathan' were larger than trees of these cultivars on other roots, and they continue to hold this position. Consequently, even though scion cultivars vary in response, trees on their own roots are not smaller than trees on seedling, while trees on M. 7a tend to be smaller than seedling.

The site of our planting was exposed to year-round westerly winds. Even though the force of these winds was reduced by an older block of trees on the west side of the orchard, most trees leaned to the east. Micropropagated trees tended to lean more than trees on seedling and were generally no better than trees on M. 7a. The amount of leaning varied with the scion regardless of the rootstock. Lean of micropropagated 'Delicious' and 'Golden Delicious' trees ranked among the poorest 4 treatments in the entire experiment. Webster et al. (9) reported that 4 cultivars of micropropagated apples were not as well anchored as trees on MM. 106 and that many trees had to be staked to prevent their collapse. While our micropropagated 'Golden Delicious' are leaning at approximately 30°, we have not yet staked these or any other micropropagated trees, although with heavier crop loads, staking may become necessary.

Yield and yield efficiency in the first year with significant bloom (1987) were best with trees on M. 7a, with little difference between seedling and micropropagated trees. This was in spite of the fact that some own-rooted

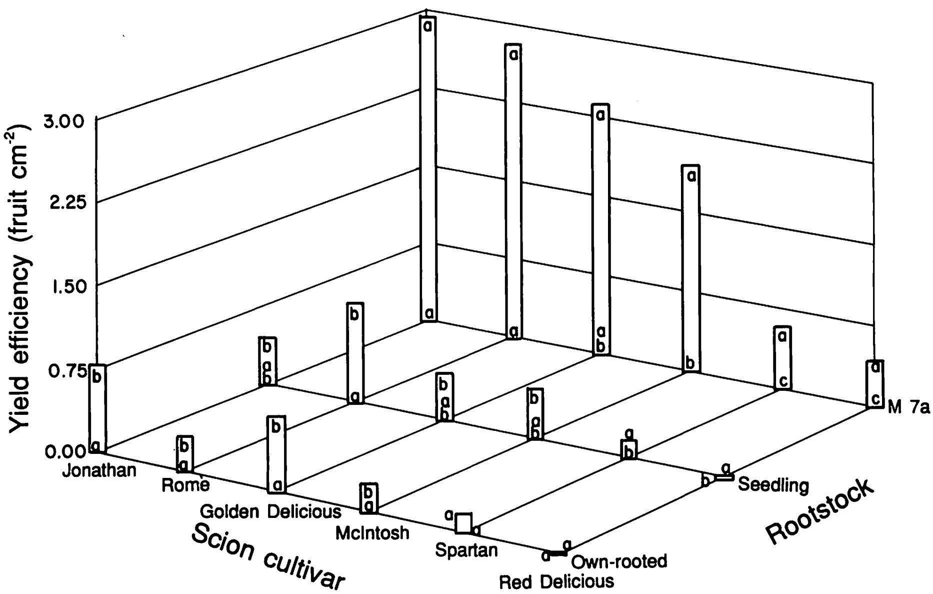

Figure 4. Yield efficiency (number of fruit per cm^2 stem cross-sectional area) in 1987 of several micropropagated apple cultivars and those on seedling and M. 7a roots planted in 1984. Letters at the top of bars determine differences among rootstocks within scions and those at the base determine differences among scions within rootstocks ($P \leq 0.05$).

trees had grown 2 years in the nursery prior to planting. There was little difference between 1- and 2-year micropropagated nursery trees in regard to their initial fruiting response. In 1988 there were no significant rootstock effects on yield (fruit weight) and yield efficiency (when ANOVA was used) although the trend in efficiency was 0.21, 0.31, and 0.36 $kg \cdot cm^{-2}$ for micropropagated, seedling, and M. 7a, respectively. The relatively large difference in yield efficiency in 1988 between trees on their own roots and those on M. 7a rootstock is, however, probably biologically significant. When a simple pairwise t-test was used to compare these two means, the result was a significant difference ($P = 0.0277$). Others (1, 7, 8, 9, 10, 11, 12) have observed that flowering and fruiting of micropropagated trees are delayed, although this at times is exacerbated by how trees are handled or the size of the trees at planting (11). While some of our cultivars were 1-year nursery trees and others were 2-year trees, this difference did not appear to affect the onset of fruiting. Rosati and Gaggioli (7) found that a micropropagated spur type 'Golden Delicious' had produced as much fruit after 4 years as trees on MM. 106, and both trees were more fruitful than trees on MM. 111. However, efficiency of the micropropagated trees was lowest and that of trees on MM. 106 was highest because of greater vigor of micropropagated trees.

Although micropropagated trees offer potential tree cost advantages for high density plantings, as described earlier (3), excessive tree size, lack of precocity, and a possible need for staking are three problems of micropropagated trees that have arisen in field testing. The tree support problem is not of great consequence, since most high density systems are supported. However, the large trees that often result from micropropagation may preclude their widespread use in high density plantings, unless genetically dwarfed cultivars become available for future use. Precocity is essential to recover the initial high cost of high density plantings and to take advantage of the high fruit prices of new cultivars. Perhaps cultural methods can be divised to overcome potential delays in bearing.

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1990 Prunus Breeders Meeting

David H. Byrne and Terry A. Bacon[1]

The prunus Breeders Meeting this year was held on May 25-26th and hosted by David Byrne and Terry Bacon of the Department of Horticultural Sciences, Texas A&M University at College Station, Texas. Prunus researchers/breeders from ten U.S.-based breeding programs in 9 states (Alabama, Arkansas, California, Florida, Georgia, New York, South Carolina, Texas and West Virginia) and from ten other countries (Australia, Brazil, Canada, China, France, Hungary, Italy, Mexico, Thailand and Yugoslavia) participated in the conference.

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