Effects of Apple Cultivar, Rootstock, and Orchard Spacing on Yields, Tree Survival, and Tree Growth

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Apple orchard design and management have changed considerably in recent years due to development of smaller trees. Spur type trees, possessing slower growth rates than standard trees, are gaining in popularity in the United States. Although size controlling rootstocks have been widely used in other countries for centuries, their acceptance in the U. S. has been slow (3). The Malling Merton (MM) rootstocks possessing wooly aphid resistance as well as size control were released in 1952 (4) and were readily accepted. The development of smaller trees led to plantings of higher densities, frequently resulting in earlier production, greater yields per acre and sometimes a shorter life span for the orchard.

The research orchard at the Plateau Experiment Station near Crossville has included size controlling rootstocks since 1953. Some rootstocks failed completely and most had a relatively short life span (5). However, the life span of standard trees was also relatively short at this location (2). Winter temperature fluctuations have caused considerable tree stress. Rootstock MM 106 was the most acceptable size controlling rootstock on the sandy loam soil of the Cumberland Plateau (5). However, tree size was larger than expected here and at other locations in the southeast (1). Rootstock MM 111, although only slightly dwarfing, also performed well. Rootstock M 7 was more dwarfing than MM 111 but suckered badly, occasionally broke at the graft union and had poor anchorage the first 10 years.

The most acceptable cultivars tested previously (6) were Golden Delicious, Red Delicious, Red Rome, Stayman, Cortland, Mutsu and two promising new early maturing cultivars Julyred and Tydeman's Red.

A new research orchard was established at Plateau Experiment Station in 1973 for the purpose of evaluating combinations of cultivars and rootstocks at selected spacings in larger tree populations than previously tested in Tennessee.

PROCEDURE

Nine cultivars were selected for the study: Golden Delicious, Red Delicious, (Topred strain), Spur Red Delicious (Redspur strain), Rome (Nured strain), Stayman (Nured strain), Mutsu, Cortland, Julyred, and Tydeman's Red. Rootstocks used were standard (seedling), MM 106, MM 111, and M. 7. An incomplete factorial selection of treatments was made due to past performances, limited land and manpower resources, and non-availability of certain cultivars and rootstocks.

Treatments of all cultivars on standard rootstocks were included in the test. Trees on standard rootstocks were spaced 20 x 30 ft. except for Spur Red Delicious trees which were spaced at 20 x 20 ft. Also, all cultivars except Spur Red Delicious were tested on MM 106 rootstock at 20 x 20 ft. Topred Delicious, Golden Delicious, and Mutsu were also included on MM 106 rootstock at 20 x 10 ft. spacing. Two other treatments consisted of Cortland trees on M.7 rootstock planted at 20 x 20 and 20 x 10 ft. spacings.

The treatments were arranged in a randomized complete block design with four replications. Each plot con-

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sisted of 3600 square feet with six trees at 20 x 30 ft., nine trees at 20 x 20 ft., and 18 trees at 20 x 10 ft. spacings.

A relatively well elevated site having good air drainage was chosen for the orchard. Soil type was a Hartsells sandy loam with a 2 to 3 ft. depth above bedrock. An initial soil test indicated a pH of 6.5, a high phosphate level, and a low potash level. Trees used in the test were one year old whips, 4 to 5 ft. high, 0.50 to 0.62 inches in diameter at time of planting except for Cortland on M.7 which were only 2 to 3 ft. tall. Trees were set in March 1973, using an 18 in. auger to dig tree holes. Trees were trained to a central leader and were summer pruned the first 2 seasons to obtain desired shape and branch angle. Limb spreaders were placed in the trees in the spring of 1975. New growth was pruned heavily annually to maintain desired tree shape and size. Weak rooted trees were staked in 1975. The stakes were removed in the spring of 1980.

Daminozide was sprayed on vigorous Mutsu and Topred trees in May, 1980 in order to reduce growth rate and enhance future fruit set. Herbicides were applied within the tree row to control weeds. Directed paraquat was used for the first two years. In following years, weeds were controlled by application of paraquat and simazine or terbacil. Row middles were maintained as mowed orchard grass sod.

A fertilizer program of 60 lbs. of nitrogen and 25 lbs. each of phosphate and potash per acre broadcast annually was used for the first four years. Boron was applied folarly at 1 lb./A in 1975. One and one half tons of dolomitic linestone was broadcast in November, 1975. No fertilization was applied during the four fruiting years.

Data collected included annual yields, percentage tree survival and annual growth rate. This information was compared by standard analysis of variance procedures.

RESULTS AND DISCUSSION

The 28 treatments were analyzed together and least significant differences (LSD) values determined for the experiment as a whole. However, the treatments were broken into separate tables for ease of showing treatment differences and trends. Therefore, the LSD values for yield in Table 1, 2, 3 and 4 are the same and inferences may be made among tables.

Spacing. Tree spacing had a significant effect on tree yield for the first four fruiting years. Yield per acre was generally greater at closer spacings during the early bearing years. Cortland trees on M.7 rootstock planted 20 x 10 ft. yielded 56%more fruit per acre for the first four fruiting years than trees spaced 20 x 20 ft. (Table 1). Mutsu trees on MM 106 yielded 31% more fruit at 20 x 10 ft. than at the 20 x 20 ft. spacing (Table 2). Topred Delicious yielded 113% more fruit at 20 x 10 ft. than at the

Table 1. Yield and growth of Cortland apple trees at different tree spacings on Tennessee Cumberland Plateau, 1977-1980.

Rootstock	Spacing (ft.)	Yield[z] (Bu/A)	(Bu/tree)	Tree Diameter[y] (in.)
M 7	20 × 10	164	0.75	4.48
M 7	20 × 20	105	0.96	4.50
Standard	20 × 30	82	1.13	5.93
LSD at 5% level		129		0.45

[z]Total yield for 1977 - 1980.
[y]Tree diameter, Nov. 1980.

20 x 20 ft. spacing. However, Redspur Delicious only had 41% greater yield at the close spacing (Table 3). Golden Delicious trees responded exceptionally well to close planting. Trees planted 20 x 10 ft. yielded over 75% more fruit than trees spaced 20 x 20 ft. (Table 4). Mutsu, Cortland and Redspur Delicious showed less yield increase from close spacing than Topred or Golden Delicious. Mutsu had a very rapid growth rate and wide angled branches. Thus, they filled the row spacing very rapidly, resulting in the small differences in yield between the two spacings on MM 106 rootstock. Redspur Delicious and Cortland trees had few limbs to develop and failed to fill the row space as quickly as other cultivars, perhaps partially explaining the greater yield increase at closer spacing than for Mutsu.

An average of 611 bushels per acre for the first 4 fruiting years was obtained for the 7 rootstock-cultivar treatments having a spacing of 20 x 10 ft. The same rootstock-cultivar combinations at 20 x 20 ft. spacing averaged only 356 bushels per acre.

Although closer spacing resulted in greater yields per acre during the early bearing years, competition between trees was beginning to limit yield per tree. The closer spacing of 20 x 10 ft. resulted in reduced yield per tree compared to 20 x 20 ft. spacing for Cortland on M.7 (Table 1), Mutsu on MM 106 (Table 2), Redspur Delicious on standard, Topred Delicious on MM 106 (Table 3), and Golden Delicious on MM 106 and MM

Table 2. Yield and growth of Mutsu apple trees at different tree spacings on Tennessee Cumberland Plateau, 1977-1980.

Rootstock	Spacing (ft.)	Yield[z] (Bu/A)	(Bu/tree)	Tree Diameter[y] (in.)
MM 106	20 × 10	596	2.74	5.69
MM 106	20 × 20	453	4.14	6.08
Standard	20 × 30	56	0.77	6.04
LSD at 5% level		129		0.45

[z]Total yield for 1977 - 1980.
[y]Tree diameter, Nov. 1980.

Table 3. Yield and growth of Topred and Redspur Delicious apple trees using different rootstocks and tree spacings on Tennessee Cumberland Plateau, 1977-1980.

Strain	Rootstock	Spacing (ft.)	Yield[z] (Bu/A)	(Bu/tree)	Tree Diameter[y] (in.)
Topred	MM 106	20 × 10	341	1.57	4.01
Topred	MM 111	20 × 10	416	1.91	4.19
Topred	MM 106	20 × 20	185	1.70	4.54
Topred	MM 111	20 × 20	170	1.56	4.61
Topred	Standard	20 × 30	4	0.06	4.78
Redspur	Standard	20 × 10	195	0.90	4.33
Redspur	Standard	20 × 20	138	1.27	4.57
LSD at 5% level			129		0.45

[z]Total yield for 1977 - 1980.
[y]Tree diameter, Nov. 1980.

111 (Table 4). Only Topred Delicious on MM 111 had not yet shown a reduced yield per tree at the closer spacing.

Closer tree spacing also generally resulted in reduced tree trunk diameter. As tree spacing was reduced from 20 x 20 ft. to 20 x 10 ft., tree trunk diameter tended to be smaller for Cortland on M.7 (Table 1), Mutsu on MM 106 (Table 2), Topred Delicious on standard (Table 3) and Golden Delicious on MM 106 and MM 111. It is assumed that the increased tree competition or increased pruning associated with closer planting resulted in the reduced tree size.

In Tables 1 - 4, yields from trees spaced 20 x 30 ft. were much less than for closer spaced trees during the first 4 fruiting years. The reduced yields per acre at 20 x 30 ft. were obviously partially due to fewer trees per acre and the large amount of tree void space within the tree row. It must be noted that the trees at the widest spacing were on standard rootstocks.

Rootstock. Rootstock selection greatly influenced fruit yield in some cases. Golden Delicious was more

Table 4. Yield and growth of Golden Delicious apple trees at different spacings and rootstocks on Tennessee Cumberland Plateau, 1977-1980.

Rootstock	Spacing (ft.)	Yield[z] (Bu/A)	Yield[z] (Bu/tree)	Tree Diameter[y] (in.)
MM 106	20 × 10	1331	6.11	4.03
MM 111	20 × 10	1232	5.66	4.49
MM 106	20 × 20	804	7.38	4.36
MM 111	20 × 20	640	5.88	4.73
Standard	20 × 30	166	2.29	5.26
LSD at 5% level		129		0.45

[z]Total yield for 1977 - 1980.
[y]Tree diameter, Nov. 1980.

Table 5. Yield of eight apple cultivars on different rootstocks for the first four fruit bearing years grown on the Tennessee Cumberland Plateau, 1977-1980.

Cultivar	Yield[z] MM 106 Rootstock[y] (Bu/A)	MM 106 Rootstock[y] (Bu/tree)	Standard Rootstock[x] (Bu/A)	Standard Rootstock[x] (Bu/tree)
Golden Delicious	804	7.38	166	2.29
Rome	496	4.55	172	2.37
Mutsu	453	4.16	56	0.77
Cortland	356	2.35	82	1.13
July Red	224	2.06	66	0.91
Stayman	198	1.82	46	0.63
Topred Delicious	185	1.70	4	0.06
Tydeman's Red	99	0.91	46	0.63
Mean	339		80	
LSD at 5% level	129		129	

[z]Total yield for 1977 - 1980.
[y]MM 106 rootstock trees spaced 20 x 20 ft.
[x]Standard rootstock spaced 20 x 30 ft.

productive on MM 106 than on MM 111 during early bearing years (Table 4). Little difference was noted concerning bearing of Topred Delicious on MM 106 and MM 111, though at the 20 x 10 ft. spacing trees on MM 111 tended to be slightly more productive (Table 3).

All cultivars included in this experiment bore more fruit the first four bearing years when grown on dwarfing rootstocks than on standard rootstocks. It is readily apparent from Table 5 that all tested cultivars were more precocious on MM 106 than on standard rootstocks. The yield of 8 cultivars averaged 3.12 bu/tree on MM 106 compared to 1.10 bu/tree on standard rootstocks or 184% more fruit. On a per acre basis, trees on MM 106 averaged 339 bu/A and trees on standard averaged 80 bu/A, or a gain of 324% by use of MM 106 as a rootstock. The greater yields per acre of trees on MM 106 was due to their precocious nature allowing more fruit per tree and at higher tree densities.

With Topred Delicious trees of the same spacing, tree trunk diameter was not different with MM 106 and MM 111 rootstocks (Table 3). However, Golden Delicious trees tended to be smaller on MM 106 than on MM 111 (Table 4). In a comparison of culti-

Table 6. Tree growth of eight cultivars grown on seedling rootstock or on MM 106 rootstock on the Tennessee Cumberland Plateau, 1980.[z]

Cultivar	Tree Diameter: Standard[y] Rootstock (in.)	MM 106[x] Rootstock (in.)	(% of standard)
Golden Delicious	5.26	4.36	83
Rome	5.48	4.26	78
Mutsu	6.04	6.08	101
Cortland	5.93	5.25	89
July Red	5.60	5.25	94
Stayman	5.79	4.27	74
Topred Delicious	4.78	4.54	95
Tydeman's Red	6.31	5.74	91
LSD at 5% level	0.45	0.45	

[z]Trees planted Spring 1973, diameter measure, Nov. 1980.
[y]Standard trees spaced 20 x 30 ft.
[x]MM 106 rootstock trees spaced 20 x 20 ft.

Table 7. Survival of apple cultivars grown on several rootstocks on the Tennessee Cumberland Plateau, 1980.[z]

Cultivar	Tree Survival: Standard (%)	MM 106 (%)	MM 111 (%)	M 7 (%)
Golden Delicious	96	96	97	—
Rome	88	86	—	—
Mutsu	75	88	—	—
Cortland	100	100	—	78
July Red	88	89	—	—
Stayman	79	92	100	—
Red Delicious	100	95	100	—
Tydeman's Red	96	81	—	—
Spur Red Delicious	97	—	—	—
LSD at 5% level	018			

[z]Trees planted Spring 1973, survival rate as of Fall 1980.

vars grown on MM 106 and standard rootstocks, it is evident that trees on MM 106 had smaller trunk diameters (Table 6). It was previously pointed out that as planting distances were reduced for a variety on a dwarfing rootstock, tree trunk growth was also reduced. Thus, reduced trunk growth rate of trees on MM 106 could have been partly due to the closer spacing of MM 106 (20 x 30 ft.). A direct comparison of the dwarfing effect due to rootstock without tree spacing influence can not be made. A comparison of growth rates indicates that some cultivars were dwarfed more by MM 106 than were others. Trunk growth of Stayman, Rome and Golden Delicious were especially reduced by MM 106 although as shown before, the rootstock had a pronounced effect on precocity of that cultivar.

Tree Survival. Tree survival 7 years after establishment ranged from 75 to 100% (Table 7). It was expected that trees on semidwarfing rootstocks would have greater mortality than trees on standard rootstocks. However, tree survival was very similar for cultivars grown on MM 106 (92%) and standard rootstocks (91%). Survival of the cultivars on MM 111 was quite high under these environmental conditions. Cortland trees on M.7 had 22% mortaility. The M.7 rootstock was weak rooted, produced numerous suckers, and exhibited symptoms of a virus disease. Several trees were lost, due to rodent damage, especially during the heavy snowfall of 1977.

Survival of Mutsu and Stayman was low on standard rootstocks and tended to be higher on some dwarfing rootstocks. Golden Delicious and Red Delicious survived well on MM 106, MM 111 and standard rootstocks for the first 7 years of growth.

Fruit Quality. Fruit quality parameters have not been evaluated for this planting. Fruit size and color have generally been excellent except during the hot, dry weather of 1980. Fruit size appeared to decrease generally as tree density increased. Golden Delicious fruit were observed to have less russet from trees on MM 106 and MM 111 compared to standard rootstock. Topred Delicious fruit had superior red color development to Spur Red Delicious fruit. Mature fruit of Rome were large and well colored, even in the dry season of 1980.

CONCLUSIONS

Golden Delicious and Rome were the most productive cultivars during the early years of production. Mutsu was quite productive on MM 106 rootstock. All cultivars were more precocious on MM 106 rootstock than standard rootstock. Increased tree density of semi-dwarfing rootstock generally resulted in reduced yield per tree but increased yields per acre during the first four fruiting years. Closer tree spacing tended to result in reduced tree size as indicated by tree trunk diameter. Tree survival of the semidwarfing rootstocks tested was generally high on sandy loam soil of the Cumberland Plateau. However, tree survival of the only M.7 rootstock treatment was relatively low at this location.

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