It was surprising, however, that the seed count was higher in the spur type strains than in the non-spur strains. Perhaps with the spur type strains, the weaker fruit buds were eliminated resulting in a higher percent set and seed count in the remaining fruit.

McIntosh strains were also compared. Macspur and Starkspur McIntosh had the poorest fruit shape rating of the McIntosh strains compared (Table 4); however, these differences were not significant at the 5% level. VC309 and the Historical McIntosh (virus tested) had significantly higher seed counts than the other strains.

There was a fair correlation ($r = .6^{**}$) between the hardiness rating and 1981 yield expressed as kg of fruit per cm^2 trunk cross-sectional area (Table 5). The percent of total clusters with fruit showed a similar correlation. Some cultviars such as Delicious and Mutsu had yields lower than can be explained simply by the flower cluster hardiness rating. These cultivars had a lower fruit set than others. The yield therefore was related not only to the hardiness rating but also to the ability of the flower clusters to set fruit.

This report is based on one year's observations. It is recognized that there are a number of different factors which affect winter hardiness and that the expression of injury may occur in many different forms. These observations should prove useful in comparing the relative winter hardiness of cultivars following conditions similar to those occurring during the winter of 1980-81.

Literature Cited

1. Proctor, J. T. A. and E. C. Lougheed. 1980. A deformity of apples of unknown origin. Can. Plant Dis. Surv. 60:13-16.

Apple Rootstock and Density Trials

CHARLES A. MULLINS AND DENNIS E. DEYTON[1]

Current production techniques of most fruit and row crops utilize higher plant densities than those used 25 to 50 years ago. Higher densities usually produce higher yields per acre with lower production costs per volume of yield. Mechanical and cultural technology have made higher crop densities feasible. Apple trees have usually been grown at rather low densities of 30 to 50 per acre, but development of size controlling rootstocks has favored higher densities. Experiments are in progress evaluating densities of thousands of trees per acre with an interest in complete mechanization including harvest (1, 2).

Dwarfing and semi-dwarfing rootstocks are presently used widely in the United States, but many problems have occurred including poor root anchorage, disease susceptibility, and lack of hardiness (2, 3, 4, 7, 8). In Tennessee tests (5), M 9 and M 26, the more dwarfing rootstocks, failed to survive more than 5 to 7 years. Trees on M 7 had problems with breakage at the graft union and had weak root

[1]Associate Professor (Crossville) and Assistant Professor (Knoxville), respectively, Department of Plant and Soil Science, University of Tennessee.

systems requiring support for the first 10 years. Rootstocks MM 106 and MM 111 performed rather well on the Hartsells sandy loam soil. However trees on both rootstocks were more vigorous than expected and those on MM 106 sometimes required support. Exposed sections of MM 106 and especially those of MM 111 were susceptible to burr knot injury which greatly reduced vigor (1, 7).

Trials with various densities of apple trees are in progress at the University of Tennessee Plateau Experiment Station near Crossville. A trial of 4 cultivars on MM 106 rootstock at a density of 272 trees per acre was established in 1966. A 1973 planting included Red Delicious, Golden Delicious, and Mutsu cultivars on selected rootstocks at various tree densities.

Procedure

1966 Planting. Golden Delicious, Red Rome, Stayman, and Red Delicious cultivars were planted on MM 106 rootstock. The trees were spaced 8 ft. apart in rows 20 ft. apart. Six trees were planted per plot in each of 4 replications. The trees were fertilized and managed to promote rather rapid early growth. All were trained to the modified central leader system. Pruning was used to maintain a height of 12 ft. and the allotted 6 to 7 ft. drive space between rows.

1973 Planting. The 1973 planting was made to evaluate the effects of selected rootstocks and spacings on 3 cultivars. Treatments included with the Topred strain of Red Delicious are as follows: (1) seedling rootstock at 30 × 20 ft. spacing; (2) MM 106 rootstock at 20 × 20 ft. spacing; (3) MM 106 rootstock at 20 × 10 ft. spacing; (4) MM 111 rootstock at 20 × 20 ft. spacing; and (5) MM 111 rootstock at 20 × 10 ft. spacing. Treatments included with the Redspur strain of spur type Red Delicious are (1) standard rootstock at 20 × 20 ft. spacing, and (2) standard rootstock at 20 × 10 ft. spacing.

Treatments with Golden Delicious included (1) standard rootstock at 30 × 20 ft. spacing, (2) MM 106 rootstock at 20 × 20 ft. spacing, (3) MM 106 rootstock at 20 × 10 ft. spacing, (4) MM 111 at 20 × 20 ft. spacing, and (5) MM 111 at 20 × 10 ft. spacing.

Mutsu trees were included on (1) standard rootstock at 30 × 20 ft. spacing, (2) MM 106 rootstock at 20 × 20 ft. spacing, and (3) MM 106 rootstock at 20 × 10 ft. spacing.

All treatments were arranged in a randomized complete block design with 4 replications. Plot size was 3600 square feet. This included 6 trees at 30 × 20 ft. spacing (73 trees/acre), and 18 trees at 20 × 10 ft. spacing (218 trees/acre). Trees were trained to a central leader with tree height at 12 to 14 ft.

General Culture. Both experiments were on well drained Hartsells sandy loam soil of about 2 ft. depth over solid sandstone. Soil pH was maintained at 6.0. Fertilizer was applied the first 4 to 5 years in each test at rates to maintain medium P and K levels and about 60 pounds N per acre. Boron was applied broadcast every 3 to 4 years. Paraquat and simazine or terbacil were used annually for weed control under the trees. A University of Tennessee Extension Service spray schedule was followed each year.

Data. Records taken included fruit yields per plot at harvest maturity, tree diameter, and tree survival. Tree diameter was measured a foot above ground level at the end of each season. All records were analyzed by analysis of variance procedures. Means were separated by Duncan's multiple range tests at the .05 level of probability.

Results and Discussion

1966 Planting. The Golden Delicious cultivar had significantly higher

mean yields over 13 years than the other 3 cultivars tested on MM 106 rootstock (Table 1). Golden Delicious and Red Rome cultivars have usually outyielded Stayman and Red Delicious cultivars at this location (6). Stayman fruit had severe cracking problems which reduced yields. The low productivity of Red Delicious trees may be due to the earlier blooming characteristics and to the severity of spring frosts at this location (6). In this test, however, tree survival probably had more effect on yields than did any other factor. Golden Delicious appeared to be very compatible with MM 106 rootstock and tree survival was 100 per cent (Table 1). The other 3 cultivars had 50 to 54 per cent tree survival which was significantly less than that of the Golden Delicious trees. Red Delicious trees tended to be more vigorous than those of the other cultivars as indicated by trunk diameter.

1973 Planting. Trees of Red Delicious (Topred strain) at the 20 × 10 ft. spacing either on MM 106 or MM 111 rootstock had significantly higher yields than did other combinations with Red Delicious (Table 2). Yields per acre were twice as much at this spacing compared to the same cultivar-rootstock combinations at 20 × 20 ft. spacing. The higher density did not result in a reduction in yield per tree during the first 5 fruiting years (1977 - 81). Trees of Red Delicious (Topred strain) on standard rootstock at 30 × 20 ft. spacing had significantly lower yields than all Red Delicious combinations except the spur type (Redspur strain) on standard rootstock at 30 × 20 ft. spacing. Trees of Red Delicious (Topred strain) on standard rootstock at 30 × 20 ft. spacing had essentially no fruit production until 1981. All other Red Delicious combinations fruited in 1977 and had annual yield increases through 1981.

The Redspur strain of Red Delicious did not yield as well as was expected. Although Redspur fruit were observed to have better lobe development and better 'typiness,' fruit of the Topred strain colored earlier and had the most acceptable color overall. Redspur trees, being spur type, had a very upright growth habit and were more difficult to train.

Neither rootstock nor spacing had a significant effect on tree survival at the end of the 1981 season (Table 2). Tree diameters were significantly higher with Red Delicious on standard rootstock at 30 × 20 ft. spacing than for all treatments except Red Delicious on MM 106 at 20 × 20 ft. spacing and spur type Red Delicious on standard rootstock at 20 × 20 ft. spacing. Higher tree density with the same rootstock tended to suppress tree diameter. Use of central leader training with strict size control has maintained all trees in the alloted space, even the more vigorous Red Delicious trees on standard rootstock.

Golden Delicious trees, although more productive than Red Delicious, responded somewhat similarly to rootstock and spacing treatments (Table 3). Trees on MM 106 and MM 111 rootstocks at 20 × 10 ft. spacing had significantly higher yields than the other 'Golden Delicious' treatments. Yields were lowest on standard rootstock at 30 × 20 ft. spacing. Golden Delicious trees on standard rootstock at 30 × 20 ft. spacing had a significantly larger tree diameter than all combinations tested except on MM 111 rootstock at 20 × 20 ft. spacing. The most vigorous Golden Delicious trees were on standard rootstock while the least vigorous were on MM 106 rootstock. All Golden Delicious combinations had a high rate of tree survival.

The Mutsu cultivar reacted much like Red Delicious and Golden Delicious (Table 4). Trees on MM 106 rootstock at 20 × 10 ft. spacing had the highest yield while trees on standard rootstock at 30 × 20 ft. spacing had the lowest yield. The magnitude

Table 1. Effect of cultivar on yield, tree survival, and tree diameter, 1966 planting.

Cultivar	Mean annual yield	Tree diameter Oct. 1981	Tree survival Oct. 1981
	bu./A.	inches	%
Golden Delicious	825 a[1]	7.3 bc	100 a
Red Rome	498 b	6.5 c	54 b
Stayman	378 b	7.6 ab	50 b
Red Delicious	338 b	8.4 a	50 b

[1]Mean separation within columns by Duncan's multiple range tests, 5% level.

Table 2. Effect of type, rootstock, and spacing on yield, tree diameter, and tree survival of the Red Delicious cultivar, 1973 planting.

Type (strain)	Rootstock	Spacing	Mean annual yield	Tree diameter Oct. 1981	Tree survival Oct. 1981
		ft.	bu./A.	inches	%
Topred	standard	30 × 20	27 e[1]	5.5 ab	92 a
Topred	MM 106	20 × 20	107 cd	4.9 bcd	92 a
Topred	MM 106	20 × 10	206 a	4.2 d	97 a
Topred	MM 111	20 × 20	93 cd	4.8 cd	100 a
Topred	MM 111	20 × 10	203 a	4.5 d	98 a
Redspur	standard	20 × 20	69 de	4.8 bcd	100 a
Redspur	standard	20 × 10	126 bc	4.6 cd	96 a

[1]Mean separation within columns by Duncan's multiple range tests, 5% level.

Table 3. Effect of rootstock and spacing on yield, tree diameter, and tree survival of the Golden Delicious cultivar, 1973 planting.

Rootstock	Spacing	Mean annual yield	Tree diameter Oct. 1981	Tree survival Oct. 1981
	ft.	bu./A.	inches	%
Standard	30 × 20	87 c[1]	5.6 a	96 a
MM 106	20 × 20	250 b	4.5 c	94 a
MM 106	20 × 10	386 a	4.4 c	96 a
MM 111	20 × 20	197 b	5.0 abc	97 a
MM 111	20 × 10	384 a	4.7 bc	97 a

[1]Mean separation within columns by Duncan's multiple range tests, 5% level.

Table 4. Effect of rootstock and spacing on yield, tree diameter, and tree survival of the Mutsu cultivar, 1973 planting.

Rootstock	Spacing ft.	Mean annual yield	Tree diameter Oct. 1981	Tree survival Oct. 1981
		bu./A.	inches	%
Standard	30 × 20	75 c[1]	6.1 a	80 a
MM 106	20 × 20	246 b	6.2 a	100 a
MM 106	20 × 10	329 a	6.0 a	87 a

[1]Mean separation within columns by Duncan's multiple range tests, 5% level.

of yield increase was less for Mutsu than for the other cultivars. This is attributed to the more rapid growth rate of the vigorous Mutsu wood. Tree growth was not significantly affected by rootstock and spacing as shown by tree diameter measurements (Table 4). Mutsu trees rapidly filled their allotted space with productive wood. Mutsu tree survival varied from 80 to 100 per cent but differences due to treatment were not significant.

Conclusions

The 1966 planting of Golden Delicious trees on MM 106 rootstock at 20 × 8 ft. spacing performed well. Trees of the cultivars Red Rome, Stayman, and Red Delicious with the same rootstock and spacing combination had only about 50 per cent survival after 16 years.

The 1973 planting showed that yields of Red Delicious and Golden Delicious trees on either MM 106 or MM 111 rootstock were almost doubled when tree density increased from 109 to 218 trees per acre. Mutsu trees responded less to the higher density, apparently because of a faster growth rate. Trees on standard rootstock at 30 × 20 ft. spacing always had a significantly lower yield per unit area than trees on either MM 106 or MM 111 rootstock at denser populations.

Heavy pruning was required to maintain trees in the allotted space, especially at the higher densities. The effort seemed justified in terms of productivity early in the life of the orchard.

Literature Cited

1. Constante, J. 1979. 2000 Trees Per Acre. American Fruit Grower. 99(3):12-13.
2. Cummins, J. and R. Norton. 1974. Apple Rootstock Problems and Potentials. New York's Food and Life Sciences Bulletin No. 41.
3. Doll, C. 1975. Observations of Apple Rootstocks, Interstocks, Bodystocks, and Cultivars in Southeast Iowa. Fruit Varieties Journal 29(1):15-17.
4. Feree, D. 1978. Performance of 15 Apple Cultivars on MM 106 and M 26. Fruit Varieties Journal 32(3):40-42.
5. Mullins, C. 1972. Twenty Year's Research with Size Controlling Rootstocks on the Cumberland Plateau. Tennessee Agriculture Experiment Station Bulletin No. 488.
6. Mullins, C. 1974. Apple Variety Performance on the Cumberland Plateau of Tennessee. Tenn. Agr. Exp. Station Bulletin No. 531.
7. Tyler, R. 1981. Rootstock Performance and Problems Under Different Soil and Climatic Conditions. Compact Fruit Tree 14:41-43.
8. Wyatt, A. 1981. Rootstock Trends in British Columbia Apple Orchards. Compact Fruit Tree. 14:10-13.