Fruit Varieties Journal 53(4):215-221 1999

Performance of Golden Delicious cv. 'Smoothee' on Dwarfing Rootstocks and Interstems in a Hot, Humid Climate

ROBERT C. EBEL,[1] ARNOLD CAYLOR,[2] JIM PITTS,[3] AND BRYAN WILKINS[4]

Abstract

This study was conducted to determine performance of Golden Delicious cv 'Smoothee' on several dwarfing rootstocks and interstems in the long growing season of the Southeastern U.S. Tree mortality was high for the dwarfing rootstocks and interstems due to flooding stress the year the trees were planted, an occasional problem in this region. The semidwarfing rootstocks with and without interstems did not differ in survival. Dwarfing interstems on semidwarfing rootstocks and dwarfing rootstocks without interstems provided adequate growth control, whereas semidwarfing rootstocks without interstems did not. Cropload density was highest with any dwarfing interstem on MM.106 EMLA and M.7A rootstocks. Yield was best on M.9 EMLA and M.26 EMLA rootstocks with no interstems. Yield efficiency was highest for M.27 EMLA and M.9 EMLA rootstocks and next with any dwarfing interstem on MM.106 EMLA and MM.111 EMLA rootstock. Mark and M.27 EMLA are not suitable in this region because of small fruit size in this experiment. Firmness and soluble solids were not strongly affected by treatment. The best performing trees were M.9 EMLA, M.26 EMLA, M.7A and MM.106 EMLA rootstocks without interstems, and any interstem on either M.7A or MM.106 EMLA rootstock. The interstems provided sufficient growth control whereas the semidwarfing rootstocks without interstems did not.

Introduction

Clonal rootstocks have been developed for size control of apple trees, however, tree growth often varies in different geographical regions (6, 16, 17). Studies must be conducted to determine performance in specific regions. The Southeastern U.S. is characterized by long, hot, and humid growing seasons, with growth starting as early as March and ending in November in some areas. Excessive vegetative growth not only increases pruning costs, but also accentuates disease and insect problems and reduces fruit quality. Growers frequently must summer prune in addition to winter prune to keep trees within their allotted space and open the canopy to allow greater light and pesticide spray penetration.

Although size control is important, there is also strong interest among growers to use trees that can be free standing, thus avoid the expense of mechanical support systems. Some dwarfing rootstocks must be mechanically supported because of their weak root systems. In the last several decades, there has been sporadic interest in using dwarfing interstems to control tree size, combined with vigorous rootstocks to improve anchorage (1, 12, 13, 14, 18, 20). The current study was conducted to determine performance of Golden Delicious cv 'Smoothee' on dwarfing interstems and rootstocks in the southeastern U.S.

Materials and Methods

The experiment was conducted at the Chilton Area Horticulture Substation in central Alabama. Average annual precipitation is 1350 mm and the 43-year average winter chilling (less than 45°F) was 1250 hours. The soil was a Ruston fine sandy loam. Before planting, the soil was limed and tilled to 46 cm (18 in.) depth.

[1]Assistant professor, Department of Horticulture, 101 Funchess Hall, Auburn University, Auburn, AL 36849.
[2]Superintendent, North Alabama Horticulture Substation, P.O. Box 1062, Cullman, AL 35055.
[3]Superintendent, Chilton Area Horticulture Substation, 120 County Road 756, Clanton, AL 35045.
[4]Research Associate, Department of Horticulture, 101 Funchess Hall, Auburn University, Auburn, AL 36849.

The study was conducted as three separate experiments, a 'dwarf rootstock experiment' with M.9 EMLA, M.26 EMLA, M.27 EMLA and Mark rootstocks tested, a 'semidwarf rootstock experiment' with seedling, MM.106 EMLA, M.7A and MM.111 EMLA rootstocks tested, and an 'interstem experiment' with all combinations of M.9 EMLA, M.26 EMLA, M.27 EMLA and Mark interstems on seedling, MM.106 EMLA, M.7A and MM.111 EMLA rootstocks tested, except there was no M.27 EMLA interstem on M.7A rootstock planted in the experiment. Bareroot Mark, M.27 EMLA, M.26 EMLA, M.9 EMLA, M.7, MM.106 EMLA, MM.111 EMLA, MM.7A and seedling trees that had not been headed back were obtained from Willow Drive Nursery, Inc. (Ephrata, WA) in the autumn of 1988, and stored in damp sawdust at ambient temperatures. In February of 1989, all shoots were headed back and the cut shoots were whip-grafted onto appropriate rootstocks for the interstem experiment. The trees were returned to the sawdust at ambient temperatures. In late March, the trees were planted into a nursery row. The grafts of the trees for the interstem experiment had extensive callus tissue present indicating that the graft union was in an advanced state of healing. All trees were budded with scion wood in June of 1989 in the nursery, with the bud on the interstem trees grafted 15 cm (6 in.) above the graft union. Two weeks later, all trees were headed back to the grafted buds to force them to grow. In early March of 1990, the trees were replanted in the field with the graft union, including the lowest graft union of the interstem trees, 5 cm (2 in.) above the soil surface.

In the dwarf rootstock experiment, the trees were planted at a 2.7 x 4.6 m (9 x 15 ft) spacing. In the semidwarf experiment, the trees were planted at a 3.7 x 6.1 m (12 x 20 ft) spacing. In the interstem experiment, the trees were planted at a 2.4 x 4.6 (8 x 15 ft) spacing. Each experiment was planted as randomized complete block design with 4 blocks in the dwarf and interstem experiments and 8 blocks in the semidwarf experiment. In all three experiments, there were three adjacent trees per treatment per block. The trees were supported by stakes at planting.

The trees were drip irrigated the first two years after planting with two, 3.7 liter/hr emitters per tree spaced 0.78 m (2 ft) from the trunk. Each tree received 30 liters of water daily when the soil appeared dry. A 1.2 m (3 ft) wide band within the tree row was maintained free of vegetation using herbicides. All trees were trained to a central leader (11). The trees were pruned to contain them within their allotted space with respect to within the tree row, and to maintain a 2.5 m tractor lane between rows. Pruning, crop thinning, pest control and nitrogen fertilization were conducted according to commercial recommendations for apple orchards in the Southeastern U.S. The crop was thinned using 0.5 to 1.0 lb a.i. in 100 gal of water per acre of Sevin when fruit were 7 to 9 mm, and hand thinned 3 to 4 weeks after full bloom.

Tree canopy height and width, trunk circumference 25 cm above the soil surface, and tree survival was determined every September. The trees bore a few fruit two years after planting, but the first significant crop occurred in 1992. Yield was determined each year from 1992 through 1996. In 1994 through 1996, ten fruit per tree were harvested in the first two weeks of August, weighed, and flesh firmness was measured on two sides of each fruit using a handheld penetrometer and with the skin pared. A wedge was cut from each apple and squeezed into a beaker and soluble solids were determined with a handheld refractometer. All growth and fruit data were taken from the middle tree, however, data were collected from adjacent trees when the middle tree had died.

Tree survival was determined each year from 1993 through 1996. The percent tree survival of the three adjacent trees per treatment per block were determined and used to determine treatment differences.

Data from each experiment were analyzed separately. Data were analyzed as randomized complete blocked designs using the General Linear Models procedure of the Statistical Analysis System

(19). In the interstem experiment, data were analyzed as an interstem by rootstock factorial with the interaction between interstem and rootstock included in the model. Where appropriate, time (year) was included in the model but the interaction of the main plot (rootstock or interstem/rootstock) and year was not included in models since only main effects of treatment were of interest and therefore tested. Means were separated using Duncan's Multiple Range Test ($P \leq 0.05$).

Results and Discussion

Survival. Tree survival was low for most rootstocks in all three experiments (Table 1), which differs from survival of most of these same rootstocks in the early years in other studies (2, 15, 16). Although tree mortality was not determined until the third year after planting, it was clear that most trees died the first year. No trees died from 1993 through 1996. Tree mortality was most likely due to flooding stress during the spring the trees were planted. Thus, survival variability among rootstocks likely indicates their tolerance to flooding stress. In the dwarfing experiment, trees on M.9 EMLA had a very low (33%) survival rate whereas Mark was quite tolerant to the wet conditions, which supports other reports (3, 10) that showed that Mark was more tolerant to flooding stress than M.26 EMLA and M.9 EMLA. However, M.9 EMLA apparently recovers more quickly than Mark and M.26 EMLA once flooding stress is relieved (9). Tree survival did not vary among rootstocks in the semidwarfing rootstocks experiment, although there was a trend of higher survival with MM.111 EMLA and seedling rootstocks. In the interstem experiment, only the interstem had an effect on survival with trees on M.9 EMLA and Mark having the highest survival rate. Tree survival appeared lower in the interstem experiment than the same rootstocks in the semidwarf experiment because the interstem experiment was located in a low spot and thus likely incurred greater flooding stress than the semidwarf experiment.

Tree growth. The experiment was terminated after the 1996 growing season because of the high tree loss. Had the experiment been allowed to continue, the trees would likely have continued to expand in height and width, assuming tree volume was not controlled by cultural practices. 'Smoothee' on some of the same rootstocks continued to grow taller and wider over a 17 year period in another study (2). Nevertheless, there were significant differences in tree growth between treatments at the conclusion of the study. In the dwarf experiment, M.27 EMLA produced the smallest trees, M.9 EMLA and M.26 EMLA produced the largest trees and Mark was intermediate. In the semidwarf experiment, The trees on seedling rootstock were largest, M.7A were smallest, and MM.111 EMLA and MM.106 EMLA were intermediate. In the interstem experiment, rootstock had no effect on growth. Trees on Mark and M.9 EMLA interstems were largest, whereas trees on M.27 EMLA and M.26 EMLA were smallest and similar. There was no abnormal growth proliferation at the ground-line on Mark rootstock unlike reports from other experiments (16).

Although a direct comparison cannot be made with trees among the three experiments, the trees with an interstem were substantially smaller than trees in the semidwarfing experiment, which likely indicates that the interstem dwarfed the trees compared to the rootstock alone. Furthermore, the interstems dwarfed the trees to sizes about the same as Mark, M.9 EMLA and M.26 EMLA in the dwarf rootstock experiment indicating that using a dwarfing interstem can greatly reduce tree growth of a semidwarfing or seedling rootstock.

There were no suckers on the dwarfing rootstocks in the dwarf experiment. Suckering was excessive on M.7A and Seedling rootstocks in the semidwarf experiment and interstem experiment, whereas suckering of MM.111 EMLA and MM.106 EMLA was low. Interstems did not influence suckering in the interstem experiment.

Cropload density, cumulative yield and yield efficiency. Cropload density was not

Table 1. Tree survival in 1993, tree size in 1996 and suckers per tree in 1993 of Golden Delicious cv 'Smoothee' on dwarfing rootstocks, semidwarfing rootstocks, and dwarfing interstems and semidwarfing rootstocks. The trees were planted in 1990[z].

	Tree survival in 1993 (%)	Tree height (m)	Tree width (m)	TCA[y] (cm^2)	Suckers per tree 1993
Dwarfing rootstock experiment					
Rootstock					
M.27 EMLA	58ab	1.3b	1.2c	5c	0
Mark	83a	2.3ab	2.1bc	28bc	0
M.9 EMLA	33b	2.5a	2.6ab	46ab	0
M.26 EMLA	42ab	3.0a	3.5a	62a	0
Semidwarfing rootstock experiment					
Rootstock					
M.7A	79	3.3b	3.0	70b	11a
MM.111 EMLA	96	3.6ab	3.1	90ab	0c
MM.106 EMLA	83	3.9ab	3.2	97ab	2bc
Seedling	92	4.1a	3.5	122a	7ab
Interstem Experiment					
Interstem					
M.27 EMLA	44b	2.2b	2.1b	22b	20
Mark	69a	2.9a	2.7a	45a	15
M.9 EMLA	67a	2.9a	2.8b	47a	19
M.26 EMLA	35b	2.6ab	2.2b	32b	22
Rootstock					
M.7A	56	2.6	2.3	33	30a
MM.111 EMLA	63	2.6	2.4	34	6b
MM.106 EMLA	42	2.6	2.4	38	6b
Seedling	54	2.9	2.8	43	36a
Significance					
Interstem (I)	*	*	*	*	NS
Rootstock (R)	NS	NS	NS	NS	*
I*R	NS	NS	NS	NS	NS

[z]'NS' = not significant, '*' indicates significant at $P < 0.05$.
[y]Trunk cross sectional area.

affected by rootstock in the dwarf experiment, and interstem in the interstem experiment (Table 2). Rootstock had an effect in the semidwarf and interstem experiments. In the semidwarf experiment, M.7A and MM.106 EMLA had the highest cropload density, MM.111 EMLA was intermediate and seedling rootstocks had the lowest cropload density. In the interstem experiment, M.7A and MM.106 EMLA had the highest cropload density whereas MM.111 EMLA and seedling had the lowest. Among experiments, cropload density was substantially higher for all

Table 2. Crop load, cumulative yield, and average yield efficiency of Golden Delicious cv 'Smoothee' on dwarfing rootstocks, semidwarfing rootstocks, and dwarfing interstems and semidwarfing rootstocks from 1992 through 1996. The trees were planted in 1990[z].

	Average cropload density (fruit/cm²)	Cumulative yield (kg/tree)	Average yield efficiency (kg/cm²)
Dwarfing rootstock experiment			
Rootstock			
M.27 EMLA	6.6	16b	0.88
Mark	4.9	37b	0.58
M.9 EMLA	5.6	116a	0.81
M.26 EMLA	4.4	118a	0.65
Significance			
Rootstock	NS	*	NS
Year	*	—[y]	*
Semidwarfing rootstock experiment			
Rootstock			
M.7A	2.8a	82a	0.45a
MM.111 EMLA	2.1b	78ab	0.32b
MM.106 EMLA	2.7a	71ab	0.42a
Seedling	1.1c	54b	0.17c
Significance			
Rootstock	*	*	*
Year	*	–	*
Interstem experiment			
Interstem			
M.27 EMLA	3.6	43b	0.52
Mark	3.7	80a	0.56
M.9 EMLA	3.5	74a	0.53
M.26 EMLA	4.6	74a	0.63
Rootstock			
M.7A	4.8a	72ab	0.68a
MM.111 EMLA	3.4b	56b	0.48b
MM.106 EMLA	4.5a	83a	0.66a
Seedling	3.1b	68ab	0.46b
Significance			
Interstem (I)	NS	*	NS
Rootstock (R)	*	*	*
I*R	NS	NS	NS
Year	*	—	*

[z]'NS' = not significant, '*' indicates significant at $P < 0.05$.
[y]Not applicable for the model.

rootstocks in the dwarf experiment compared to semidwarfing rootstocks in the semidwarf experiment. The interstems increased cropload density over the semidwarf rootstocks alone but not to the same level as M.27 EMLA and M.9 EMLA in the dwarf experiment. Thus, an additional benefit of using dwarfing interstems may be higher fruit set, in addition to the dwarfing characteristic of the interstem and the improved anchorage of the semidwarfing rootstock.

Cumulative yield was much higher for M.9 EMLA and M.26 EMLA than Mark and M.27 EMLA in the dwarf rootstock experiment. In the semidwarf rootstock experiment, M.7A had the highest, seedling had the lowest and MM.111 EMLA and MM.106 EMLA had intermediate cumulative yields. In the interstem experiment, M.27 EMLA had the lowest yield whereas the other interstems had similar yields. Trees on MM.106 EMLA had the highest yields, trees on MM.111 EMLA had the lowest and trees on M.7A and seedling were intermediate. Yields were best on M.9 EMLA and M.26 EMLA for all three experiments.

Yield efficiency was not significantly different in the dwarfing rootstocks experiment, but there was a trend towards higher efficiency with M.27 EMLA and M.9 EMLA than Mark and M.26 EMLA. M.9 EMLA and M.26 EMLA are commonly used rootstocks in the southeastern U.S. In the semidwarfing rootstock experiment, M.7A and MM.106 EMLA had higher yield efficiencies than MM.111 EMLA and seedling rootstocks. MM.111 EMLA is still sometimes used in the southeast. However, it has been shown that trees on MM.111 EMLA developed fewer lateral branches and less fruiting wood compared to MM.106 EMLA (5), which may explain the lower yield efficiency in the current study. The interstems in the interstem experiment did not affect yield efficiency, but the rootstocks affected yield efficiency in a manner similar to the effect in the semidwarfing experiment. MM.106 EMLA and M.7A had similar yield efficiencies, which were higher than seedling

Table 3. Fruit quality of Golden Delicious cv 'Smoothee' on dwarfing rootstocks, semidwarfing rootstocks, and dwarfing interstems and semidwarfing rootstocks from 1994 through 1996. The trees were planted in 1990[z].

	Fruit weight (g)	Firmness (lbs)	Soluble solids (%)
Dwarfing rootstock experiment			
Rootstock			
M.27 EMLA	147b	7.3	16.4a
Mark	130c	10.3	16.1ab
M.9 EMLA	158ab	9.5	15.7ab
M.26 EMLA	165a	8.9	15.5b
Significance			
Rootstock	*	NS	*
Year	*	*	*
Semidwarfing rootstock experiment			
Rootstock			
M.7A	164	10.4	15.9
MM.111 EMLA	161	10.7	16.0
MM.106 EMLA	160	9.9	15.9
Seedling	155	11.4	16.2
Significance			
Rootstock	NS	NS	NS
Year	*	*	*
Interstem experiment			
Interstem			
M.27 EMLA	153	10.2	15.9
Mark	158	10.1	15.9
M.9 EMLA	163	9.8	16.0
M.26 EMLA	156	10.3	16.0
Rootstock			
M.7A	164	10.2	16.2
MM.111 EMLA	152	10.0	16.0
MM.106 EMLA	157	10.3	16.2
Seedling	159	9.9	15.5
Significance			
Interstem (I)	NS	NS	NS
Rootstock (R)	NS	NS	NS
I*R	NS	NS	NS
Year	*	*	*

[z]'NS' = not significant, '*' indicates significant at $P < 0.05$.

and MM.111 EMLA. Trees on M.27 EMLA and M.9 EMLA appeared to have the highest yield efficiencies of all three experiments. Use of interstems improved yield efficiency over those of semidwarfing rootstocks alone.

Fruit quality. Fruit were much smaller on Mark rootstock than the other three dwarfing rootstocks (Table 3), which was not due to cropload density. M.27 EMLA produced larger fruit than Mark, but the fruit were still smaller than M.26 EMLA with M.9 EMLA intermediate. Mark and M.27 EMLA rootstocks tend to promote excessive cropload that reduce fruit size, and thus require aggressive handthinning (4), although these rootstocks may also inherently produce small fruit at any cropload. However, cropload density was no better for Mark than M.26 EMLA and M.9 EMLA, yet fruit size on these rootstocks was larger than on Mark. These results may indicate that Mark is not tolerant to the hot growing seasons in the Southeastern U.S. The Southeastern U.S. also has occasional droughts and Mark has been shown to be less tolerant to drought stress than MM.111 EMLA and M.9 EMLA (7, 8). Fruit weight did not vary among rootstocks in the semidwarf and interstem experiments. Fruit weight for M.9 EMLA and M.26 EMLA rootstocks in the dwarf experiment were generally similar in fruit size to the other two experiments, which indicates that these rootstocks would be beneficial in the Southeastern U.S in terms of yield efficiency without a negative effect on fruit weight. Firmness was not affected by rootstock within each experiment, however, fruit from dwarfed trees tended to be softer than on semidwarf and seedling trees with and without dwarfing interstems, which likely indicates advanced maturity. Soluble solids were not affected in the interstem and semidwarf rootstock experiments, and were only slightly affected in the dwarfing rootstock experiment.

Conclusions

M.27 EMLA and Mark rootstock are not suitable in the southeastern U.S. because of small fruit size, low tree vigor and need for mechanical support. In areas subjected to poor water drainage, M.27 EMLA, M.9 EMLA, and M.26 EMLA should be avoided. M.7A and MM.106 EMLA were the best semidwarfing rootstocks compared to MM.111 EMLA and seedling because of better cropload density, yield and yield efficiency. All the interstems/rootstock combinations performed well except trees with M.27 EMLA had low yields. The use of interstems greatly reduced tree size and improved yield efficiencies without negatively affecting fruit quality compared to semidwarfing rootstocks alone. Therefore, interstems are a viable option for reducing tree growth while the semidwarfing rootstock provides better anchorage compared to a dwarfing rootstock alone.

Literature Cited

1. Autio, W. R. and W. J. Lord. 1988. Tree characteristics, fruiting, and mineral nutrition of apple trees on M.27 EMLA and three interstocks. HortScience 23:983-985.
2. Barden, J. A. and R. P. Marini. 1997. Growth and fruiting of a spur-type and standard strain of 'Golden Delicious' on several rootstocks over eighteen years. Fruit Var. J. 51:165-175.
3. Barritt, B. H. 1995. New dwarfing rootstocks compared with standards. Good Fruit Grower 46:19-21, 23, 24.
4. Barritt, B. H., B. S. Konishi, and M. A. Dilley. 1995. Performance of three apple cultivars with 23 dwarfing rootstocks during 8 growing seasons in Washington. Fruit Var. J. 49:158-170.
5. Dozier, W. A., H. E. Burgess, W. A. Griffey, E. L. Mayton, A. J. Latham, H. J. Amling, and C. A. Kouskolekas. 1976. Performance of selected apple rootstocks in the Piedmont area of central Alabama. Bulletin 484. Agricultural Experiment Station, Auburn University, Auburn, AL.
6. Ferree, D. C. 1987. Growth and production of 'Starkspur Supreme Delicious' apple on 9 rootstocks in the NC-140 cooperative planting. Fruit Var. J. 41:31-39.
7. Fernandez, R. T., R. L. Perry, and J. A. Flore. 1997. Drought response of young apple trees on three rootstocks: growth and development. J. Amer. Soc. Hort. Sci. 122:14-19.
8. Fernandez, R. T., R. L. Perry, and J. A. Flore. 1997. Drought response of young apple trees on three rootstocks. II. Gas exchange, chlorophyll fluorescence, water relations, and leaf abscisic acid. J. Amer. Soc. Hort. Sci. 122:841-848.
9. Fernandez, R. T., R. L. Perry, J. A. Flore, and R. M. McLean. 1997. Photosynthesis, 14C-photosynthate distribution and shoot and root growth of young apple trees on 3 rootstocks exposed to flooding. Acta Horticulturae 451:351-359.
10. Fernandez, R. T., R. L. Perry, R. M. McLean, and A. R. Otero. 1994. Water stress factors and apple rootstock performance. Compact Fruit Tree. 27:37-40.
11. Heinicke, D.R. 1975. High-density apple orchards-planning, training, and pruning. USDA Agr. Handbook 458. 34 pp.
12. Heweston, F. N. 1942. Growth and yield of Steele Red apple trees as influenced by the use of various double-worked interstocks. Proc. Amer. Soc. Hort. Sci. 40:264-268.
13. Heweston, F. N. 1944. Growth and yield of McIntosh apple trees as influenced by the use of various intermediate stem pieces. Proc. Amer. Soc. Hort. Sci. 45:181-186.
14. Lord, W. J., D. W. Greene, R. A. Damon, Jr., and J. H. Baker. 1985. Effects of stempiece and rootstock combinations on growth, leaf mineral concentrations, yield, and fruit quality of 'Empire' apple trees. J. Amer. Soc. Hort. Sci. 110:422-425.
15. NC-140. 1991. Abnormalities in 'Starkspur Supreme Delicious' on nine rootstocks in the 1980-81 NC-140 cooperative planting. Fruit Var. J. 44:213-219.
16. NC-140. 1991. Performance of 'Starkspur Supreme Delicious' apple on 9 rootstocks over 10 years in the NC-140 cooperative planting. Fruit Var. J. 45:192-199.
17. NC-140. 1996. Performance of the NC-140 cooperative apple rootstock planting: 1. Survival, tree size, yield and fruit size. Fruit Var. J. 50:6-11.
18. Norton, R. L. 1983. Interstems: Advantages, problems, and various interactions. Compact Fruit Tree 16:83-88.
19. SAS Institute. 1988. SAS/STAT user's guide, release 6.03. SAS Inst., Cary, N.C.
20. Simons, R., R. Hayden, P. Domoto, F. Morrison, G. Brown, W. Lord, R. Perry, M. Warmund, D. Ferree, and E. Stang. 1986. NC-140 1976 cooperative apple interstem planting. Fruit Var. J. 40:108-115.