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Growth and Fruiting of a Spur-Type and a Standard Strain of 'Golden Delicious' on Several Rootstocks Over Eighteen Years

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Abstract

'Goldspur' a spur-type, and 'Smoothee,' a standard strain, of 'Golden Delicious' apple were evaluated on several rootstocks/interstems for 18 years. The dwarfs included Malling 9 (M.9), M.26, M.9/Malling Merton 106 (MM.106), and M.9/MM.111; the semi-dwarfs were M.7, MM. 106, and MM.111. Five single-tree-plots were used. In-row spacings were varied with anticipated tree vigor and ranged from 1.8 to 5.5 m; between-row spacing was constant at 6.1 m. Both 'Goldspur' and 'Smoothee' trees were larger in trunk cross-sectional area (TCA) and height on M.26 and M.9/MM.111 than on M.9 or M.9/MM.106. Tree size on the three semi-dwarf rootstocks was largely unaffected by rootstock. Overall, the most root suckers occurred on trees of both strains on M.9/MM.111 and M.7. Yield per tree for both strains tended to be greater on M.26 and M.9/MM111 than on either M.9 or M.9/MM.106. Although not significantly different, per-tree yields tended to be higher on MM.111 than on M.1 or.MM.106. Crop density, yield efficiency, and average fruit weight varied relatively little among the various scion/rootstock combinations.

Introduction

The use of clonally propagated size-controlling rootstocks has become standard practice in modern apple orchards. With the absence growth control chemicals, genetic dwarfing is the main choice for control of tree size and productivity. Although pruning and training are used to affect tree size, the degree of tree size restriction possible by pruning and training is quite limited.

There have been many reports of rootstock evaluation published over the past few decades. Many have been preliminary in nature, often providing data for five years up to a rather common maximum of 10 years. These reports are obviously very useful, but there is also the need for long-term experiments in which rootstock performance is evaluated for more than 10 years. Because of the great precocity of the very dwarfing rootstocks, yield data over only a 5-10 year period may tend to bias conclusions in their favor, while in longer term studies, less precocious stocks may well overcome their lack of precocity with heavy sustained yields in later years. Such studies have been very informative (4, 7, 9, 14, 15, 16).

The experiment from which these data come was established to evaluate the long-term performance of spur and standard strains of 'Delicious' and 'Golden Delicious' on several rootstocks in the dwarf and semi-dwarf categories. The orchard design used was somewhat of a departure from that used in many rootstock trials. First, the dwarfing and semi-dwarfing rootstocks were separated into different trials. Secondly, the cultivars were put into separate trials and the spur-types were separated from the standard strains within each cultivar. Finally, the in-row spacing was varied to accommodate the anticipated tree size.

Materials and Methods

The experiment was conducted at the Virginia Tech Horticultural Research Farm near Blacksburg VA. The soil is a clayey, mixed, mesic Typic Hapludult. Prior to clearing in 1974, the site had been in apple trees for at least ten years; the site was covercropped in 1975. In the spring of 1976 lime was broadcast at 4.5 T/ha. Three-meter-wide strips were plowed and

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disced; rows were planted in the middle of each strip. Holes were dug with a 45 cm auger.

Trees of a uniform size for this experiment were purchased from a commercial nursery in MI. The total experiment consisted of standard,and spur-type strains of 'Delicious' and 'Golden Delicious'; only 'Golden Delicious' data are presented herein. Rootstocks and interstems were as follows: M.9, M.26, M.9/MM.106, M.9/MM.111, M.7, MM.106, and MM.111.

The 'Delicious' trees were set in three-tree plots and the 'Golden Delicious' were in single tree plots. All trees were planted with the graft union (lower graft union of interstem trees) 3-4 cm above the soil line. Three rows of 'Delicious' alternated with single rows of 'Golden Delicious.' Because of the diversity of anticipated tree sizes, the rootstocks were divided into dwarf (M.9, M.26, M.9/MM.106, and M.9/MM.111) and semi-dwarf to vigorous (M.7, MM.106, and MM.111) groups, and each group was treated as a separate experiment. Also because of expected differences in tree size, the spur-type and standard growing strains of each cultivar were put in separate experiments. The net result was that we had four experiments, each of which is analyzed separately as a randomized complete block design with, five replications. Blocks represented different locations in the orchard. All trees on M.9 were supported by a 2.1 m treated wood post; no other trees were supported.

Throughout the experiment the between-row spacing was 6.1 m. Tree spacings were varied according to expected tree vigor and as listed in Table 1. Where trees or plots with different spacing met, the mean of the two spacings was used between those trees.

Throughout the study, fertilizer (N only) was broadcast uniformly, regardless of tree spacing or cultivar. Additional lime was applied as indicated by soil tests. Weeds were controlled in the row by application of herbicides in a 1m strip. No irrigation was used; row middles were mowed periodically to minimize competition with the trees. Pruning, pest control, fruit thinning, and pre-harvest drop control were done according to local recommendations. All trees were trained to a central leader utilizing the head and spread system (5). Tree height was restricted to a maximum of approximately 5m, and trees were pruned as necessary to maintain drive rows of approximately 2.4m.

At harvest the fruit from each 'Golden Delicious' tree were counted and their total mass determined. In the early years, tree height and tree spread were measured; in later years these measurements were made less frequently. Trunk circumferences were measured annually at 40 cm above the soil line. Root suckers were counted annually early in the study and occasionally thereafter. When a tree broke off or died, it was dropped from the experiment; data for each year are based on the surviving trees.

Statistical analyses. Yield, fruit weight, crop density, and yield efficiency data were tested with analysis of variance using Type III sums of squares of SAS's General Linear Models (GLM) Procedure (17). When there were no missing data, means were separated with Duncan's multiple range test ($P \leq 0.05$). When tree mortality resulted in unequal numbers of observations per rootstock, the LSMEANS option of GLM was used to estimate the rootstock means that would be expected had there been equal numbers of trees for each rootstock. The PDIFF option was used to compare the LSMEANS.

Tree height, tree spread, trunk circumference, and total yield were measured annually, except as indicated above. These types of measurements taken on the same tree over time are often correlated and residuals may not be independent. Therefore the H-F condition (6), which is required for univariate analysis of variance F-tests for effects involving time and interactions with time, may not hold. The H-F condition was evaluated with the sphericity test using the PRINTE option of the REPEATED statement of the GLM Procedure as recommended by Littell

Table 1. In-row spacing of 'Golden Delicious' apple trees in rootstock trial[z] (planted 1976).

Rootstock interstock	'Goldspur' Tree spacing (m)[y]	'Goldspur' Trees/ha	'Smoothee' Tree spacing (m)[y]	'Smoothee' Trees/ha
Dwarf				
M.9	1.8	896	2.4	672
M26	2.4	672	3.0	538
M.9/MM.106	3.0	538	3.7	448
M.9/MM.111	3.0	538	3.7	448
Semi-dwarf				
M.7	3.7	448	4.3	384
MM.106	4.3	384	4.9	336
MM.111	4.9	336	5.5	298

[z]Between-row spacing was 6.1 m throughout the experiment.
[y]When trees at different spacings were adjacent, the mean of the two spacings was used.

(11). Because the sphericity test was rejected for all response variables ($P \leq 0.001$), these data were analyzed with a multivariate repeated-measures analysis. Because multivariate tests tend to be conservative, the G-G adjustments for the univariate tests were evaluated as suggested by Littell (11), and generally agreed with the multivariate tests. When the year by rootstock interaction was significant ($P \leq 0.05$), data were analyzed with analysis of variance by year and LSMEANS were compared with PDIFF. Because PDIFF is similar to a multiple t-test, Bonferroni's Simultaneous Confidence Interval Procedure was used to hold the experimentwise error rate at approximately $\alpha = 0.05$. This procedure involves dividing the p-value ($\alpha = 0.05$) by the number of two-way comparisons being made (10).

Results and Discussion

Tree survival. Tree survival was 80% or more for all scion/rootstock combinations for years 1 through 5 (Table 2). From 0 to 40% tree loss occurred in years 6 through 10. For years 11 through 18, tree losses were minimal. Losses occurred from several causes including tree breakage from heavy crops and breakage at the graft union. A very few died from undetermined causes. There were no tree losses due to obvious cases of fireblight or collar rot. Because of the small total number of trees, definitive conclusions cannot be made as to differences in survivability due to either scion cultivar or rootstock/interstock. It is worth noting, however, that for both scion strains, survival of trees on MM.111 was 100% for the 18 years of the study.

Tree survival data have been included as a part of the recent NC-140 reports on rootstock performance (12, 13), but many earlier reports offered no tree survival data (4, 7, 9, 18). After ten years, mean tree survival (across all sites) in the NC-140 trials ranged from 61 to 97% for the 1980 trial (12) and 66 to 100% for the 1984 trial (13). Although tree losses in our trial were much higher than ideal, the losses are not greatly different than other trials where survival data are provided. Because of the nature of tree losses in this study, it is our opinion that many of the

Table 2. Tree survival (%) of 'Golden Delicious' as influenced by strain and rootstock (planted 1976).

Rootstock/interstock	'Goldspur' 1980	1985	1990	1993	'Smoothee' 1980	1985	1990	1993
Dwarf								
M.9	100	60	60	60	100	80	80	60
M.26	100	80	80	80	80	80	60	60
M.9/MM.106	80	60	60	60	100	80	80	80
M.9/MM.111	100	60	60	60	80	80	80	80
Semi-dwarf								
M.7	100	100	100	80	80	80	80	80
MM.106	100	80	80	60	80	60	60	60
MM.111	100	100	100	100	100	100	100	100

Table 3. Trunk cross sectional area (cm^2) of 'Golden Delicious' trees as influenced by strain and rootstock (planted 1976).

	'Goldspur'				'Smoothee'			
Rootstock/Interstock	1980	1985	1990	1993	1980	1985	1990	1993
Dwarf								
M.9	6b[z]	26b	61c	91b	12	48b	100bc	134b
M.26	14a	55a	122ab	163a	17	69a	169a	217a
M.9/MM.106	9b	33ab	74bc	98b	14	45b	82c	105c
M.9/MM.111	10ab	55a	131a	185a	16	64a	132ab	181ab
Significance (P ≤ F)	0.006	0.017	0.028	0.016	0.100	0.030	0.001	0.001
Semi-dwarf								
M.7	16	88	204	245	24	102	198	292
MM.106	17	66	130	125	25	105	202	253
MM.111	18	84	194	269	25	137	288	381
Significance (P ≤ F)	0.735	0.348	0.238	0.111	0.898	0.449	0.074	0.670

[z]When F value is significant ($P \leq 0.05$), LSMEAN separation within scion strain, rootstock size group, and year by PDIFF at a comparison-wise error rate of ($P \leq 0.008$) for dwarfs and ($P \leq 0.016$) for semi-dwarf.

losses would have been prevented by more careful management of the young trees. In particular we feel that the losses reflect lack of tree support which is now considered by many to be essential for dwarf trees.

Tree size. On the dwarf rootstocks, both strains tended to have greater TCA on M.26 and M.9/MM.111 than on M.9 or M.9/MM.106 after 5, 10, 15, and 18 years (Table 3). 'Smoothee'/M.9 and M.26 tended to have TCAs considerably larger than 'Goldspur'/M.9 and M.26, while the two strains had similar TCAs on both interstock combinations. At no time during the study were there significant differences in TCA among the three semi-dwarf rootstocks for either strain of 'Golden Delicious,' but trees of 'Goldspur' on MM.106 tended to have, smaller TCAs than 'Goldspur' on M.7 or MM.111, which were quite similar.

The results with tree height (Table 4) were generally similar to those with TCA. 'Goldspur' trees on M.26 and M.9/MM.111 were taller than those on M.9 or M.9/MM.106 at the end of the experiment. Although the same differences occurred with 'Smoothee' in 1988, they were not significant in 1993. 'Goldspur'/MM.106 trees were shorter than those on M.7 or MM.111. At no time were

Table 4. Tree height (cm) of 'Golden Delicious' trees as influenced by strain and rootstock (planted 1976).

	'Goldspur'				'Smoothee'			
Rootstock/Interstock	1980	1985	1990	1993	1980	1985	1990	1993
Dwarf								
M.9	160bc[z]	214bc	255	329b	198	272ab	294b	383
M.26	178a	252ab	318	395a	204	285ab	399a	470
M.9/MM.106	129c	210c	257	333b	206	248b	281b	370
M.9/MM.111	175ab	263a	280	400a	213	305a	361a	445
Significance (P ≤ F)	0.046	0.012	0.075	0.016	0.543	0.051	0.001	0.080
Semi-dwarf								
M.7	204	308	392	515a	258	352	422	538
MM.106	183	280	336	358b	254	358	447	548
MM.111	189	322	396	538a	254	384	449	552
Significance (P ≤ F)	0.406	0.334	0.091	0.006	0.978	0.597	0.362	0.919

[z]When F value is significant ($P \leq 0.05$), LSMEAN separation within scion strain, rootstock size group, and year by PDIFF at a comparison-wise error rate of ($P \leq 0.008$) for dwarfs and ($P \leq 0.016$) for semi-dwarf.

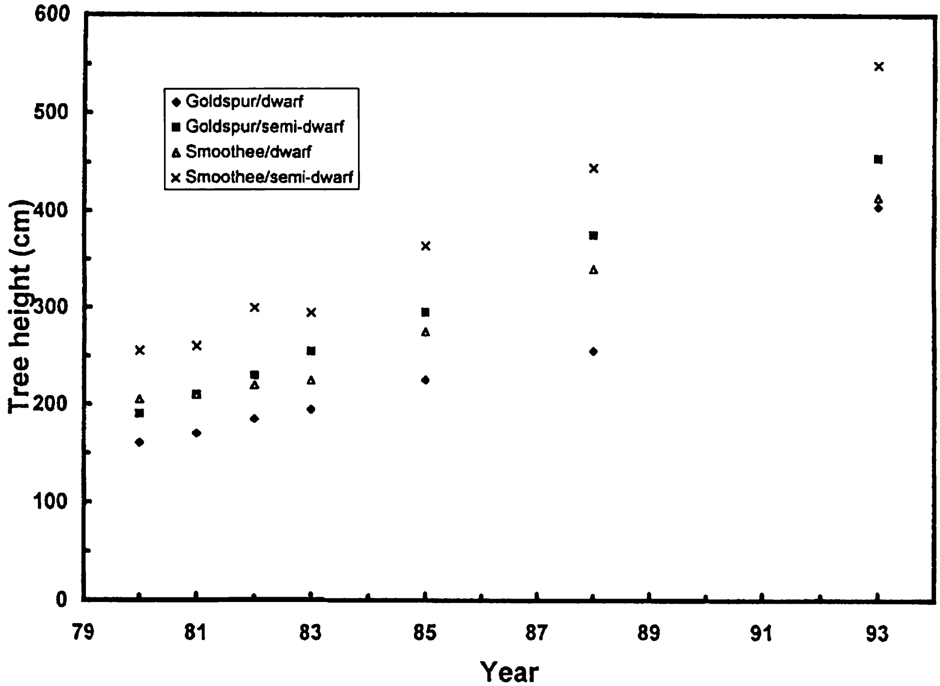

Figure 1. Tree height (cm) of 'Golden Delicious' trees as influenced by strain and rootstock; dwarf: mean for M.9, M.26, M.9/MM.106, and M.9/MM.111; semi-dwarf: mean for M.7, MM.106, and MM.111. Trees planted in 1976.

there significant differences in height of 'Smoothee' on the three semi-dwarf rootstocks. Tree height, especially of 'Smoothee' on the more vigorous rootstocks, was restricted by pruning. The trends in mean tree heights for the four groups of trees from 1980 through 1993 were quite similar and the difference between the shortest and tallest groups changed little between 1980 and 1993 (Fig 1).

Tree spread did not vary within strain and rootstock group (Table 5). It appears that the semi-dwarf rootstocks produced trees of greater height and spread than did the dwarfing combinations. An important feature of our orchard design is that row spacing was constant throughout the experiment, and that the use of full-sized orchard equipment dictated a minimum alley width of about 2.4m. Therefore, especially in the later years, the spread of trees on the semi-dwarfing rootstocks was more restricted by pruning than was the spread of trees on the dwarf rootstocks. For example 'Smoothee' on the dwarf stocks at tree spacings of 2.4 to 3.7m was relatively unrestricted at a row spacing of 6.1m whereas 'Smoothee'/MM.111 at a tree spacing of 5.5m required much more severe pruning to keep the drive middle open.

Root suckers. In the dwarf rootstock group, both strains produced the most root suckers on M.9/MM.111 at 10 and 15 years (Table 6). In the semi-dwarf rootstock group the most root suckers were on trees on M.7 at 10 and 15 years, but this difference was significant only for 'Smoothee.' With those scion/rootstock combinations that tended to form root suckers, the severity of the problem continued to increase up through the 15th year. M.7 has long been known to be very prone to form root suckers (15). Using two strains of 'McIntosh,' Autio and

Table 5. Tree spread (cm) of 'Golden Delicious' trees as influenced by strain and rootstock (planted 1976).

	'Goldspur'			'Smoothee'		
Rootstock/interstock	1985	1990	1993	1985	1990	1993
Dwarf						
M.9	90	215	261	136	312	322
M.26	123	282	350	161	345	419
M.9/MM.106	90	202	281	155	294	315
M.9/MM.111	91	273	334	166	358	401
Significance (P ≤ F)	0.078	0.340	0.329	0.282	0.112	0.119
Semi-dwarf						
M.7	128	310	377	191	385	416
MM.106	126	311	361	167	383	422
MM.111	114	278	363	176	420	498
Significance (P ≤ F)	0.491	0.614	0.892	0.188	0.119	0.135

Southwick (2) reported that suckering was much higher with M.7 and M.9/MM.111 than with M.9 or M.26. Noteworthy is that trees of both strains of 'Golden Delicious' M.9/MM.111 suckered considerably worse than did trees on M.9/MM.106, perhaps due to the greater vigor of the former combination.

Crop density. Over the course of this experiment, differences in crop density within the scion/rootstock groups were neither large nor consistent; data are presented as means for 3 to 14 year periods (Table 7). There was a trend toward higher crop densities with 'Smoothee' than 'Goldspur,' even in the 1980-1985 period. Both strains tended to have higher crop densities on the dwarf rootstocks than on the semi-dwarf rootstocks

Cropping. For both 'Goldspur' and 'Smoothee,' cumulative yields through 1993 tended to be greater for trees on M.26 and M.9/MM.111 than on M.9 on M.9/MM106, but the differences were rarely significant (Table 8). Cumulative per-tree yields of both strains through 1993 tended to be higher on MM.111 than on MM.106 or M.7. Yields of 'Smoothee'/MM.111 tended to be the highest of all combinations after both 15 and 18 years.

Table 6. Number of rootsuckers on 'Golden Delicious' trees as influenced by strain and rootstock (planted 1976).

	'Goldspur'			'Smoothee'		
Rootstock/interstock	1980	1985	1990	1980	1985	1990
Dwarf						
M.9	1	2b[z]	8b	0	6	16b
M.26	0	0b	8b	0	0	0b
M.9/MM.106	0	1b	12b	1	6	6b
M.9/MM.111	2	27a	61a	3	18	38a
Significance (P ≤ F)	0.115	0.001	0.001	0.089	0.064	0.004
Semi-dwarf						
M.7	0	10	33	0	24a	98a
MM.106	0	0	0	0	1b	5b
MM.111	3	9	16	0	0b	2b
Significance (P ≤ F)	0.098	0.120	0.315	0.410	0.004	0.001

[z]When F value is significant (P ≤ 0.05), LSMEAN separation within scion strain, rootstock size group, and year by PDIFF at a comparison-wise error rate of (P ≤ 0.008) for dwarfs and (P ≤ 0.016) for semi-dwarf.

Table 7. Crop density [z](fruit/cm² TCA) of 'Golden Delicious' trees as influenced by strain and rootstock (planted 1976).

	'Goldspur'				'Smoothee'			
Rootstock/interstock	1980-'85	1986-'90	1991-'93	1980-'93	1980-'85	1986-'90	1991-'93	1980-'93
Dwarf								
M.9	4.5	5.3	3.9	4.7	5.8	5.8	4.0	5.4
M.26	3.8	3.8	3.9	3.8	4.6	4.9	4.2	4.6
M.9/MM.106	4.4	5.0	4.0	4.5	5.2	6.0	5.6	5.6
M.9/MM.111	2.7	4.0	3.3	3.3	5.5	6.2	4.2	5.5
Mean	3.9	4.5	3.8	4.1	5.3	5.7	4.5	5.3
Semi-dwarf								
M.7	2.9	3.7	3.0	3.2	3.9	4.0	2.5	3.6
MM.106	3.5	4.8	4.0	4.1	4.3	4.7	3.1	4.2
MM.111	2.4	3.4	3.4	3.0	2.5	4.2	2.9	3.2
Mean	2.9	4.0	3.4	3.4	3.6	4.3	2.8	3.7

[z]Data are means for the years indicated.

When yields are expressed as T/ha for the actual tree spacings, there is a shift in which yields of trees on M.9 tended to equal or exceed yields of trees on M.9/MM.111, while yields of trees on M.26 tended to be the greatest (Figs. 2A and 3A). Noteworthy is the marked increase in yields after 1985, the tenth year of the experiment. For example the average annual yields of 'Smoothee' on the four dwarfing rootstocks/interstocks were 20, 44.3, and 54.2 T/ha/yr for 1981-85, 1986-90, and 1991-93, respectively. Cumulative yield (T/ha) was relatively low over the first ten years. These low early yields were likely partially the result of excessive pruning, especially the use of heading cuts in the early years. In comparing the data in Table 1 and Table 5, it is apparent that in the early years, tree canopies were capturing only a limited proportion of the available light. It is also important to note that the cumulative yields were based on actual tree spacing. In some published literature, projected yields are based on hypothetical spacings. Differences among the semi-dwarf rootstocks in T/ha for either strain were minimal (Figs. 2B and 3B).

Table 8. Cumulative yield (kg.tree) of 'Golden Delicious' trees as influenced by strain and rootstock (planted 1976).

	'Goldspur'				'Smoothee'			
Rootstock/interstock	1980	1985	1990	1993	1980	1985	1990	1993
Dwarf								
M.9	2	94	326	491	6	179	520bc[z]	754
M.26	4	153	483	744	5	221	767a	1190
M.9/MM.106	2	105	356	515	3	150	461c	709
M.9/MM.111	5	94	430	698	7	231	730ab	1069
Significance ($P \le F$)	0.137	0.204	0.337	0.184	0.172	0.131	0.045	0.073
Semi-dwarf								
M.7	2	165	634	862	2	262	815	1134
MM.106	4	158	554	628	3	268	890	1253
MM.111	5	151	636	1035	1	234	1086	1582
Significance ($P \le F$)	0.340	0.932	0.733	0.236	0.116	0.587	0.559	0.386

[z]When F value is significant ($P \le 0.05$), LSMEAN separation within scion strain, rootstock size group, and year by PDIFF at a comparison-wise error rate of ($P \le 0.008$) for dwarfs and ($P \le 0.016$) for semi-dwarfs.

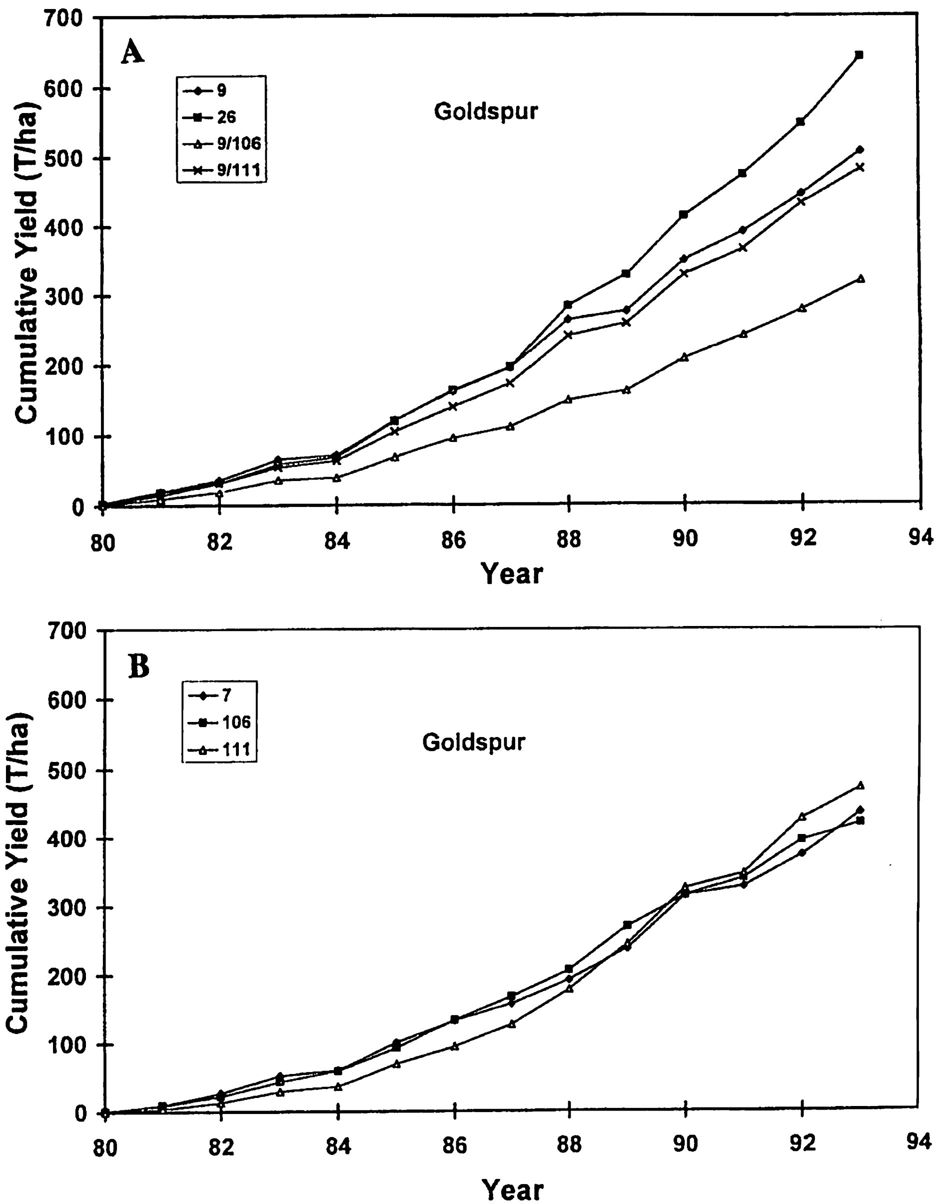

Figure 2. Cumulative yields (T/ha) of 'Goldspur Golden Delicious' on (A) dwarf and (B) semi-dwarf rootstocks. Trees planted in 1976.

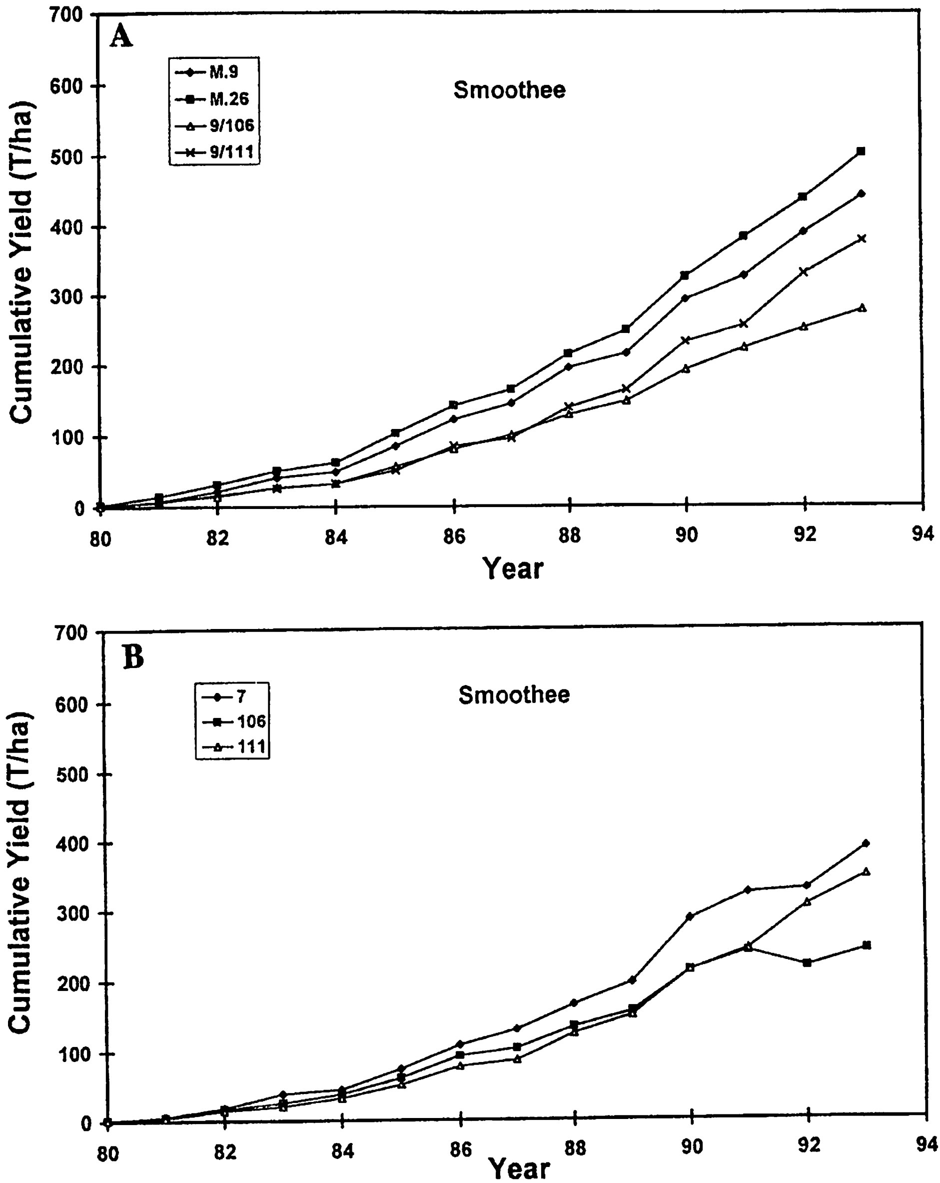

Figure 3. Cumulative yields (T/ha) for 'Smoothee Golden Delicious' on (A) dwarf and (B) semi-dwarf rootstocks. Trees planted in 1976.

Table 9. Cumulative yield efficiency (kg/cm^2 TCA) of 'Golden Delicious' trees as influenced by strain and rootstock (planted 1976).

	'Goldspur'			'Smoothee'		
Rootstock/Interstock	1985	1990	1993	1985	1990	1993
Dwarf						
M.9	3.6	5.3	5.4	3.7	5.2	5.6
M.26	2.8	4.0	4.6	3.2	4.5	5.5
M.9/MM.106	3.2	4.8	5.3	3.3	5.6	6.8
M.9/MM.111	1.7	3.3	3.8	3.6	5.5	5.9
Mean	2.8	4.4	4.8	3.4	5.2	6.0
Semi-dwarf						
M.7	1.9	3.1	3.5	2.6	4.1	3.9
MM.106	2.4	4.3	5.0	2.6	4.4	5.0
MM.111	1.8	3.3	3.8	1.7	3.8	4.2
Mean	2.0	3.6	4.1	2.3	4.1	4.4

For both dwarf and semi-dwarf groups, per-tree yields through 1993 averaged about 50% higher for 'Smoothee' than for 'Goldspur.' On a T/ha basis, 'Smoothee' tended to outyield 'Goldspur' by more than 20% for both the dwarf and semi-dwarf groups. The relative productivity of 'Smoothee' and 'Goldspur' is in agreement with the report by Seeley et al.(18).

The low productivity of 'Goldspur' combined with its excessive fruit russeting (3) offer little optimism for its commercial future. The greater desirability of the standard-growing strain of 'Granny Smith' over two spur type strains was reported by Larsen et, al.(8).

Yield efficiency. Differences in cumulative YE were not large nor particularly consistent, but tended to be greater for the dwarf than semi-dwarf rootstocks (Table 9). Overall trends in YE were generally similar to those reported by Larsen and Fritts (7). In our study, cumulative YE tended to be higher for 'Smoothee' than for 'Goldspur,' while Larsen et al.(9), found the reverse, but used standard 'Golden Delicious.'

Fruit size. Over the course of this study, average fruit weight varied from about 145 to about 200 g but there were no consistent effects of strain or interstock/rootstock (Table 10). For most cultivar/interstock/rootstock combinations, there was a slight downward trend in fruit size with increasing tree age. This trend does not appear to be the result of increasing crop density which exhibited no particular pattern (Table 7)

Row spacing of 6.1 m for 'Goldspur'/M.7 and 'Smoothee'/M.9/MM.106

Table 10. Average fruit weight (g) of 'Golden Delicious' fruit as influenced by strain and rootstock (planted 1976).

	'Goldspur'				'Smoothee'			
Rootstock/interstock	1980-'85	1986-'90	1991-'93	1980-'93	1980-'85	1986-'90	1991-'93	1980-'93
Dwarf								
M.9	185	165	166	174	186	172	166	176
M.26	195	183	155	182	193	184	177	186
M.9/MM.106	198	179	167	185	174	170	159	169
M.9/MM.111	194	177	154	179	175	165	164	169
Semi-dwarf								
M.7	184	199	146	182	161	169	179	168
MM.106	192	183	170	184	171	163	170	168
MM.111	199	181	164	185	178	169	183	176

and M.9/MM.111 (tree spacing of 3.7 m) allowed for a traditional drive middle of approx. 2.4 m. Unfortunately, there was excessive space between the rows of smaller combinations. By the same token, considerable pruning was required to keep the drive middle open between the more vigorous combinations. The constant row spacing likely led to underestimating the potential per-hectare yields of trees on M.9 and M.26. It is impossible to assess the effect of row spacing on the more vigorous combinations. Containment pruning would logically suppress cropping, but the higher than ideal tree populations should at least partially make up for those losses.

Although one can disagree with the use of standard row spacing and variable tree spacing, we believe that in this experiment the choice was sound. When the drive middle width of 2.4 m is added to the 15-yr-old tree spread in 1990 (Table 5), the 6.1 m row spacing used is within 10% for all but three treatments. We also believe that when trees are spaced to provide normal competition, a more realistic estimate of yield potential is possible than when trees are spaced so far apart as to avoid competition. A similar approach was used by Autio and Southwick (1, 2) and Larsen et al. (8).

The separation of dwarf from semi-dwarf rootstocks avoided the possibility of a tree on M.9 being adjacent to a tree on MM.111. Obviously, with new rootstocks about which much less is known, such spacing adjustments would be very difficult.

The low number of replications combined with single-tree reps meant that even a few tree losses were an obvious problem. It is readily apparent that the utilization of 8-10 reps would have been very desirable.

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