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Evaluation of a Spur and a Standard Strain of 'McIntosh' on Three Rootstocks and One Dwarfing Interstem Over Ten Years[1]

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Abstract

Performance of 'Rogers Red McIntosh' and 'Macspur' was evaluated on M.7A, M.26, M.9, and M.9/MM.111 rootstocks. Trees on M.9 were either staked or trained to a 2.1-m vertical trellis. After 10 years, trees on M.7A were the largest. Those on M.26 and M.9/MM.111 were similar in size, and trees on M.9 were the smallest. 'Rogers' trees were larger than 'Macspur' trees. Trees on M.9 were the most precocious, with the greatest bloom and fruit set in the third and fourth growing seasons. Trees on M.7A yielded the most fruit through the tenth season, followed by those on M.26. Staked trees on M.9 yielded the least. 'Rogers' yielded more than 'Macspur,' but yield efficiency was greater for 'Macspur' than 'Rogers.' The most yield efficient trees were trellised and on M.9, significantly more efficient than staked trees on M.9. Trees on M.26 and M.9/MM.111 were less efficient than those on M.9, but were significantly more efficient than trees on M.7A. Tree spread was used to calculate potential tree density and potential yield per hectare. The greatest potential yields per hectare would be from trellised trees on M.9, the lowest yields would be from trees on M.9/MM.111. Trees on M.7A, M.26, and M.9 (staked) would produce intermediate and similar yields per hectare over the first 10 growing seasons. 'Macspur' would outyield 'Rogers.' The most surface red color was obtained on fruit from trees on M.9/MM.111. Fruit from trees on M.9 and M.26 were similarly colored, and the least red color occurred on fruit from trees on M.7A. 'Macspur' fruit were more highly colored than 'Rogers' fruit. Fruit weight was greatest for trees on M.9.

In a 1915 bulletin from the New York Agricultural Experiment Station, Hall (9) summarized the work of U. P. Hedrick and concluded that dwarf apple trees were not commercially viable. Many subsequent studies have refuted that conclusion (e.g., 11, 15, 16). It has taken many years, however, for dwarf trees to become commercially accepted in the U.S. A recent survey (1) found that only 14% of the acreage in New England planted between 1985 and 1989 was to dwarf trees, but of the acreage which was to be planted between 1990 and 1994, 62% would be to dwarf trees.

NC-140 (14, 15) has evaluated many dwarfing rootstocks extensively, but only 'Delicious' has been used as a scion. Additionally, much research has evaluated spur strains, which give some degree of dwarfing (e.g., 4, 5). Studies must occur throughout the apple growing regions, to evaluate rootstocks with cultivars and strains of regional importance.

This study was initiated to evaluate four rootstock treatments (M.7, M.26, M.9, M.9/MM.111) with a spur and standard strain of 'McIntosh' ('Macspur' and 'Rogers Red,' respectively) as scions. Additionally, trees on M.9 were either staked or trellised to evaluate two simple training systems for those trees that require permanent support.

Materials and Methods

'Rogers Red McIntosh' and 'Macspur' trees on M.7A, M.26, M.9, or M.9/MM.111 rootstocks were planted at the University of Massachusetts Horticultural Research Center, Belchertown, MA in the spring of 1979. The M.9 portion of the interstem trees was

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20 cm long. The soil was a Montauk fine sandy loam. Trees were planted with the graft union, or in the case of M.9/MM.111 the top graft union, approximately 7 cm above the soil surface. Trees on M.9 either were staked with a permanent, six-cm square, wooden post extending 2.5 m above the soil or were trained as oblique palmettes (18) to a vertical, four-wire trellis, with wires at 0.6, 1.1, 1.6, and 2.1 m.

The experimental design was a randomized complete block with seven replications. Within each block, four trees were planted per strain-rootstock/training combination. Data were collected from all trees. The two middle trees were used for data analysis; however, in situations where a middle 'Macspur' tree reverted to a nonspur growth habit, data from one of the outer trees were substituted for analysis.

All rows were spaced 6.1 m apart, but spacing within rows varied with treatment. 'Rogers'/M.7A trees were spaced 4.9 m. 'Macspur'/M.7A, 'Rogers'/M.26, and 'Rogers'/M.9/MM.111 trees were spaced 4.3 m. 'Macspur'/M.26 and 'Macspur'/M.9/MM.111 trees were spaced 3.7m. 'Rogers'/M.9 trees, staked or trellised, were spaced 3.0 m, and 'Macspur'/M.9 trees, staked or trellised, were spaced 2.4 m.

Staked and free-standing trees were trained as central leaders with minimal pruning. All fertility and pest management was performed similarly for all treatments per local recommendations.

In 1981, the total number of flower clusters were counted per tree, but all were removed to prevent fruiting. In 1982, two typical limbs were selected per tree and the number of flower clusters and final fruit set (after June drop) were counted on each limb. Limb circumference was measured and transformed to limb cross-sectional area.

Root suckers were counted and cut each August. Each year, trunk circumference was measured in October and transformed to trunk cross-sectional area. Beginning in 1982, yield was assessed for each tree. After the tenth growing season (1988), tree height and in-row spread were measured. Tree spread was used to calculate potential tree density. It was assumed that an appropriate in-row spacing would be 90% of the spread after ten years, and the between-row spacing would be the in-row spacing plus 2.1 m. Also, it was assumed that trellis rows would be spaced 4.0 m apart, regardless of tree spread in the row.

On September 8, 1987 and September 12, 1988, 20 fruit were harvested randomly from throughout the canopy of each data tree. Percent surface red color and grade were assessed for each fruit. In 1988, fruit were weighed, and firmness was measured with an Effegi penetrometer (Effegi, Alfonsine, Italy), one puncture per fruit. Four-fruit samples were harvested randomly from the periphery of each tree on September 8, 1987 and September 12, 1988 for internal ethylene assessment. After harvest, a one-ml gas sample was removed from the core cavity of each fruit and injected into a gas chromatograph for ethylene determinations.

All data were subjected to analysis of variance. Where there was a significant interaction of 'McIntosh' strain and rootstock/training treatment, values presented are means of rootstock/training treatment within each strain; otherwise, overall means are presented for rootstock/training treatments and strains. Rootstock/training treatment means were separated by Duncan's New Multiple Range Test and strain means were separated by F test.

Results and Discussion

Tree Size

Table 1 reports the size of trees in this experiment. There was no interaction of strain and rootstock/training

Table 1. Tree size at the end of the tenth growing season, potential planting density, and cumulative root suckering of 'Rogers Red McIntosh' and 'Macspur' trees on M.7A, M.26, M.9, or M.9/MM.111 planted in 1979.[z]

Treatment	Trunk cross-sectional area (cm^2)	Tree height (cm)	Tree spread (cm)	Potential planting density (trees/hectare)[y]		Cumulative root suckers per tree
				Rogers	Macspur	
M.7A	156.4 a	452 a	462 a	358	425	149 a
M.26	76.1 b	333 b	376 bc	500	629	7 b
M.9 (stake)	32.5 c	262 c	297 d	735	897	7 b
M.9 (trellis)	32.7 c	279 c	358 c	728	898	9 b
M.9/MM.111	66.5 b	328 b	401 b	426	590	105 a
Rogers	84.9 °°	343 °°°	405 °°°	--	--	73 °°
Macspur	60.8	318	352	--	--	37
Significance:						
Root	°°°	°°°	°°°	--	--	°°°
Strain	°°	°°°	°°°	--	--	°°
Root x Strain	ns	ns	ns	--	--	ns

[x]Mean separation within rootstock treatment by Duncan's new multiple range test, P = 0.05. Separation of strain means by F test.
[y]Distance between trees = 0.9 x tree spread in 1988. Distance between rows = 2.1 m + distance between trees. Trellis row spacing = 4 m.
°°°, °°, ns: Significant at P = 0.001, P = 0.01, or nonsignificant, respectively.

system, so only overall means will be discussed. Rootstock treatments gave predictable results, with M.7A resulting in the largest trees. Trees on M.26 and those on M.9/MM.111 were next smallest and similar in size. Trees on M.9 were the smallest.

'Rogers' trees were significantly larger than 'Macspur' trees. This result is in conflict with previously reported evaluations of 'Macspur' which suggested that tree size was not different from a standard strain (19). This difference may be related to the tendency

Table 2. Bloom density in the third growing season and bloom density and fruit set in fourth growing season of 'Rogers Red McIntosh' and 'Macspur' trees on M.7A, M.26, M.9, or M.9/MM.111 planted in 1979.[z]

Treatment	Bloom density 1981 (clusters/cm^2 TCA[y])		Bloom density 1982 (clusters/cm^2 LCA[x])	Fruit set, 1982	
	Rogers	Macspur		Fruit/cm^2 LCA[x]	Fruit/100 blossom clusters
M.7A	8.9 c	8.6 b	6.9 d	2.3 c	35
M.26	15.4 b	13.1 b	11.3 bc	3.7 bc	35
M.9 (stake)	38.4 a	34.7 a	16.8 a	6.3 a	39
M.9 (trellis)	36.6 a	38.3 a	12.5 b	5.1 ab	42
M.9/MM.111	8.5 c	13.0 b	9.0 cd	3.6 bc	39
Rogers	21.6 ns		10.5 ns	3.7 °°	36 ns
Macspur	21.5		12.1	4.7	40
Significance:					
Root	°°°		°°°	°°°	ns
Strain	ns		ns	°°	ns
Root x Strain	°		ns	ns	ns

[z]Mean separation within rootstock treatment by Duncan's new multiple range test, P = 0.05. Separation of strain means by F test.
[y]TCA = trunk cross-sectional area.
[x]LCA = limb cross-sectional area.
°°°, °°, °, ns: Significant at P = 0.001, P = 0.01, P = 0.05, or nonsignificant, respectively.

Table 3. Annual yield per tree of 'Rogers Red McIntosh' and 'Macspur' trees on M.7A, M.26, M.9, or M.9/MM.111 planted in 1979.[z]

	Yield per tree (kg)							
Treatment	1982	1983	1984	1985	1986	1987	1988	Cumulative
M.7A	12.8 a	26.4 b	27.6 a	63.7 a	34.2 a	88.3 a	81.3 a	334 a
M.26	9.3 bc	20.0 b	20.6 b	49.4 b	25.5 b	76.0 b	53.6 b	254 b
M.9 (stake)	9.2 bc	18.6 b	19.8 b	32.0 d	14.8 c	50.0 c	32.8 c	177 d
M.9 (trellis)	11.2 ab	19.2 b	28.0 a	36.4 cd	23.7 b	55.9 c	35.2 c	210 c
M.9/MM.111	8.1 c	16.5 b	20.2 b	41.4 c	24.5 b	51.7 c	40.8 c	203 c
Rogers	10.9 °	21.7 °	25.1 °	48.8 °	22.3 °	66.9 ns	53.2 °	249 °°°
Macspur	9.3	18.6	21.4	40.4	26.8	61.9	44.3	223
Significance:								
Root	°°	°°	°°	°°°	°°°	°°°	°°°	°°°
Strain	°	°	°	°	°°	ns	°	°°°
Root x Strain	ns	ns	ns	ns	ns	ns	ns	ns

[z]Mean separation within rootstock treatment by Duncan's new multiple range test, P = 0.05. Separation of strain means by F test.
°°°, °°, °, ns: Significant at P = 0.001, P = 0.01, P = 0.05, or nonsignificant, respectively.

of 'Macspur' to revert to a nonspur growth habit. In this experiment, approximately 30% of the 'Macspur' trees exhibited a nonspur growth habit after 10 seasons. Since four trees were planted per experimental plot, data from nonspur trees were eliminated from the statistical analysis and replaced with data from adjacent spur-type trees, thus allowing evaluation of "real" 'Macspur'; however, it does not represent the mix of spur and nonspur trees that a grower would normally experience with 'Macspur.' This distinction is academic, since the tendency to reversion makes further planting of 'Macspur' undesirable.

Tree spread was used to calculate potential planting densities, which are also presented in Table 1. Potential densities ranged from 358 trees per hectare for 'Rogers'/M.7A to 898 trees per hectare for trellised 'Macspur'/M.9.

Table 4. Annual yield efficiency of 'Rogers Red McIntosh' and 'Macspur' trees on M.7A, M.26, M.9, or M.9/MM.111 planted in 1979.[z]

	Yield efficiency (kg/cm^2)							
Treatment	1982	1983	1984	1985	1986	1987	1988	Cumulative
M.7A	0.57 c	0.74 b	0.50 c	0.88 d	0.39 c	0.77 d	0.54 c	2.25 d
M.26	0.68 c	0.88 b	0.63 c	1.24 c	0.54 bc	1.23 c	0.77 b	3.64 c
M.9 (stake)	1.22 b	1.74 a	1.33 b	1.63 b	0.61 b	1.85 b	1.02 a	5.70 b
M.9 (trellis)	1.56 a	1.84 a	1.99 a	2.08 a	1.12 a	2.38 a	1.15 a	7.04 a
M.9/MM.111	0.64 c	0.80 b	0.66 c	1.12 c	0.54 bc	0.96 cd	0.66 bc	3.30 c
Rogers	0.87 °	1.11 °	0.95 ns	1.28 °°	0.50 °°°	1.26 °°	0.76 ns	3.88 °°
Macspur	1.00	1.29	1.09	1.50	0.78	1.61	0.89	4.89
Significance:								
Root	°°°	°°°	°°°	°°°	°°°	°°°	°°°	°°°
Strain	°	°	ns	°°	°°°	°°	ns	°°
Root x Strain	ns	°	ns	ns	ns	ns	ns	ns

[z]Mean separation within rootstock treatment by Duncan's new multiple range test, P = 0.05. Separation of strain means by F test.
°°°, °°, °, ns: Significant at P = 0.001, P = 0.01, P = 0.05, or nonsignificant, respectively.

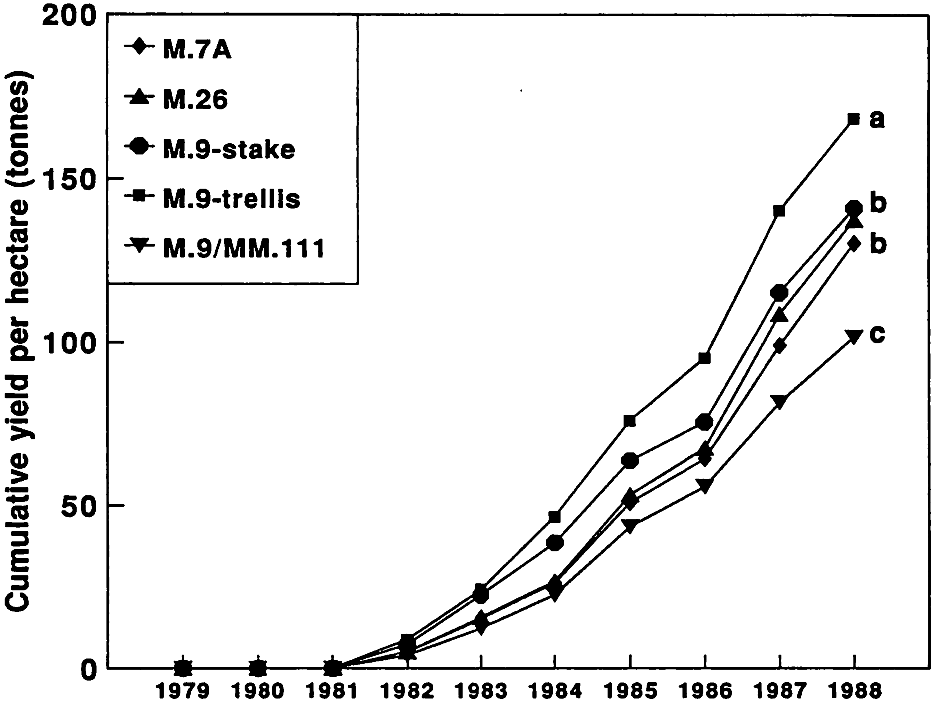

Figure 1. Yield per hactare (calculated potential) of 'McIntosh' trees on M.7A, M.26, M.9, or M.9/MM.111 planted in 1979. Since the interaction of rootstock and strain was nonsignificant, overall rootstock means are presented. Means for final cumulative yield per hectare separated by Duncan's new multiple range test, P = 0.05.

Root Sucker Production

M.7A is a rootstock which generates a large number of root suckers near the base of the trunk (15). In this study, both M.7A and M.9/MM.111 generated a large number of root suckers, exceeding 100 per tree over the first 10 growing seasons (Table 1). M.26 and M.9 produced fewer than 10 per tree over the same period.

Interestingly, 'Rogers' trees produced nearly twice as many root suckers as 'Macspur' trees (Table 1). Possibly, the physiological signal that reduces lateral branch development in the scion of a spur-type tree also prevents shoot initiation in the rootstock. Looney et al. (12) suggested that this physiological signal may be related hormonal interactions resulting in morphological differences in shoots of spur and standard strains of 'McIntosh.'

Precocity

At the beginning of the third growing season (1981), the number of blossom clusters per tree was counted to assess precocity (Table 2). For both strains of 'McIntosh,' M.9 resulted in the greatest bloom density. For 'Rogers,' M.26 resulted in more bloom than M.7A and M.9/MM.111. There was no difference overall between the two strains. In the fourth growing season (1982), the number of blossom clusters and fruit set (after June drop) were counted on two limbs per tree (Table 2). Staked trees on M.9 had the greatest bloom density, and trees on M.7A had the lowest. Fruit set followed a similar pattern. Bloom density was similar for the two strains; however, 'Macspur' had a higher fruit set after June drop.

Yield

Yield per tree was roughly correlated to tree size, with two exceptions (Table 3, Figure 3). Trees on M.9/MM.111 and those on M.26 were similar in size; however, trees on M.26 yielded significantly more than those on M.9/MM.111. Also, trellised trees on M.9 yielded significantly more than staked trees on M.9. This difference can be attributed to the support of the lateral branches in the trellised tree, maintaining branch vigor for a longer period of time. Also, the difference may relate to the canopy structure, with a larger portion of the upper canopy filled by fruiting surface in the trellised tree.

Yield efficiency (yield per trunk cross-sectional area) often is used to estimate potential productivity of a particular strain/rootstock combination. In this study, M.9 resulted in the most yield efficient trees, with trellised trees being more efficient than staked trees (Table 4). Yield efficiency of trees on M.26 and M.9/MM.111 was similar and intermediate, and trees on M.7A were the least efficient. 'Macspur' trees were significantly more efficient than 'Rogers' trees.

These differences in yield efficiency follow support the earlier reports that the more dwarfing rootstocks are more efficient (e.g., 6, 14, 15), spur strains are more efficient than standard strains (e.g., 4, 8, 13), and trellised trees are more yield efficient than staked trees (5, 7).

Does yield efficiency accurately describe potential productivity? Potential planting density (Table 1) and yield per tree (Table 3) were used to estimate potential yield per hectare (Table 5). These calculations suggest that 'Macspur' would produce more fruit per hectare than 'Rogers' and that trellised M.9 trees would produce more fruit than any of the other rootstock

Table 5. Annual yield per hectare (calculated potential) of 'Rogers Red McIntosh' and 'Macspur' trees on M.7A, M.26, M.9, or M.9/MM.111 planted in 1979.[z]

	Yield per hectare (tonnes)							
Treatment	1982	1983	1984	1985	1986	1987	1988	Cumulative
M.7A	5.0 b	10.2 b	10.9 c	24.7 b	13.4 b	34.8 b	31.4 a	130 b
M.26	5.0 b	10.7 b	10.8 c	26.8 ab	14.2 b	41.2 ab	28.8 ab	138 b
M.9 (stake)	7.4 a	15.0 a	16.1 b	25.2 b	11.8 b	39.8 ab	25.8 b	142 b
M.9 (trellis)	8.9 a	15.3 a	22.3 a	29.4 a	19.3 a	45.2 a	28.0 ab	168 a
M.9/MM.111	4.0 b	8.3 b	10.2 c	21.0 c	12.2 b	25.8 c	20.2 c	102 c
Rogers	5.9 ns	11.5 ns	13.6 ns	24.8 ns	11.6 ***	34.7 **	26.5 ns	129 ***
Macspur	6.2	12.4	14.5	26.0	16.8	40.0	27.2	143
Significance:								
Root	***	***	***	**	***	***	***	***
Strain	ns	ns	ns	ns	***	**	ns	***
Root x Strain	ns	ns	ns	ns	ns	ns	ns	ns

[z]Mean separation within rootstock treatment by Duncan's new multiple range test, P = 0.05. Separation of strain means by F test. ***, **, ns: Significant at P = 0.001, P = 0.01, or nonsignificant, respectively.

treatments. Trees on M.7A and M.26 and staked trees on M.9 would produce similar and intermediate amounts of fruit per hectare, and trees on M.9/MM.111 would be the least productive per hectare. Yield efficiency assessments undervalued the potential of M.7A and overvalued the potential of M.9/MM.111. This inconsistency also occurred in the 1980/81 NC-140 Rootstock Planting (15), where trees on M.27 EMLA were some of the most yield efficient but among the lowest in potential yield per hectare. Additionally, Ferree et al. (7) compared various training systems and found, as noted above, that trellised 'Golden Delicious'/M.9 trees were more yield efficient than individually staked 'Golden Delicious'/M.9 trees, but because those staked trees were planted at a much higher density and trained to a slender spindle system, they outyielded the trellised trees. As researchers, we must re-evaluate the use of yield efficiency as an accurate measure of productivity.

Fruit Characteristics

The internal ethylne level of fruit in 1987 and 1988 was not consistently affected by rootstock or strain (Table 6). The percent surface red color in 1987 and 1988 was highest for fruit from trees on M.9/MM.111 and lowest for fruit from trees on M.7A (Table 6). M.26 and M.9 resulted in fruit with similar and intermediate percent surface red color. 'Macspur' fruit were red colored over a higher percentage of their surface than 'Rogers' fruit. When these fruit were graded (Table 6), a higher percentage of 'Macspur' fruit made the U.S. Extra Fancy grade than did 'Rogers' fruit. The rootstock/training effect on the percent U.S. Extra Fancy of 'Macspur' fruit followed a similar pattern as red color; however, with 'Rogers,' fewer fruit from trellised trees on M.9 made the U.S. Extra Fancy grade than those from staked trees on M.9. Apparently, enough shade resulted in the trellis to prevent the red color from developing sufficient intensity to be graded Extra

Table 6. Fruit characteristics of 'Rogers Red McIntosh' and 'Macspur' trees on M.7A, M.26, M.9, or M.9/MM.111 planted in 1979.[z]

	Internal ethylene concentration (log ppm)		Surface red color 1987 = 1988	U.S. Exta Fancy 1987 = 1988 (%)		Fruit weight 1988	Flesh firmness 1988
Treatment	1987	1988	(%)	Rogers	Macspur	(g)[y]	(N)
M.7A	-2.2 bc	-0.6 a	56 c	33 d	41 c	136 c	67.1 bc
M.26	-1.7 a	-0.6 a	59 b	48 bc	75 ab	152 b	68.1 ab
M.9 (stake)	-1.9 ab	-0.6 a	60 b	57 b	72 ab	159 a	66.9 bc
M.9 (trellis)	-2.4 c	-0.7 a	59 b	36 cd	65 b	160 a	66.6 c
M.9/MM.111	-2.0 abc	-0.6 a	65 a	77 a	84 a	132 c	68.6 a
Rogers	-2.0 ns	-0.7 °°°	50 °°°	50 °°°		146 ns	68.1 °°°
Macspur	-2.1	-0.5	61	67		149	66.9
Significance:							
Root	°	ns	°°°	°°°		°°°	°
Strain	ns	°°°	°°°	°°°		ns	°°°
Root x Strain	ns	ns	ns	°		ns	ns
Load covariate	ns	ns	--	--		°°	--
Weight covariate	--	--	--	--		--	ns

[z]Mean separation within rootstock treatment by Duncan's new multiple range test, P = 0.05. Separation of strain means by F test.
[y]Least-squares means adjusted for crop load.
°°°, °°, °, ns: Significant at P = 0.001, P = 0.01, P = 0.05,or nonsignificant, respectively.

Fancy. Clearly, this result suggests that summer pruning is necessary in a trellis planting to allow for adequate red color development.

As has been noted in other studies (2, 3, 10, 17), M.9 resulted in the largest fruit (Table 6). Trees on M.7A and M.9/MM.111 produced the smallest fruit. Firmness was highest for fruit from trees on M.9/MM.111 and lowest for fruit from trellised trees on M.9. 'Rogers' fruit were firmer than 'Macspur' fruit.

Conclusions

This study showed that 'Macspur' acts like spur strains of other cultivars, i.e. it is a smaller than standard tree which is more productive. Furthermore, with 'McIntosh' as a scion, M.9 produced the smallest and most efficient trees in the study, and when trained to a trellis, trees on M.9 had the greatest yield potential per hectare. Although M.7A resulted in a tree which was not yield efficient, trees on M.7A had a potential productivity similar to those on M.26 and staked trees on M.9. Rather than productivity, more significant concerns with the use of M.7A include poor fruit coloration, small fruit size, and large canopy volume (requiring more time to prune and harvest and more spray material per acre than the smaller trees). In this study, trees on M.9/MM.111 performed very poorly, suggesting that it is not commercially viable.

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