Fruit Varieties Journal 49(3):171-178 1995

Performance of Three Apple Cultivars with 22 Dwarfing Rootstocks During 8 Seasons in Ohio

D. C. FERREE,[1] P. M. HIRST,[2] J. C. SCHMID,[1] AND P. E. DOTSON[1]

Abstract

Rootstocks in this trial produced a continuum in tree size that could logically be grouped with the Malling standards as follows: M.27 size group = B.146, P.16, P.22, Mark and MAC.9; M.9 size group = B.9, V.1, V.3, P.2, M.9EMLA, CG.10, MAC.39 and C6; M.26 size group = V.2; M.7 size group P.1, V.4, V.7, OAR1. The virus-free selections M.9EMLA and Mark did not differ significantly in size or cropping from the original selection of M.9 and MAC.9, respectively. In general, as tree size increased, trunk cross-sectional area (TCA) growth increment was greater as the trees aged. The following rootstocks had relatively high biennality indexes on both 'Macspur McIntosh' and 'Redchief Delicious' the most biennial cultivars in this trial: CG.10, M.9, MAC.39, V.2, V.4, V.7, M.7EMLA. 'Macspur McIntosh' on OAR1 was characterized by having long shoots and large numbers of non-flowering spurs, while 'Macspur McIntosh' on Mark, M.27EMLA and MAC.9 tended to have short shoots and the fewest non-flowering spurs and vegetative shoots. The following rootstocks tended to increase the density of flowering spurs on 'Macspur McIntosh': M.9, M.26-EMLA, V.4, M.7EMLA and V.1. 'Lawspur Rome Beauty' was the most productive and efficient with the lowest bienniality index and was intermediate in tree size and TCA change compared to 'Macspur McIntosh' and 'Redchief Delicious.'

Introduction

Size-controlling and efficient rootstocks are the foundation of modern orchard systems. Unfortunately, most of the widely used desirable dwarfing rootstocks are very susceptible to fireblight (2, 9) or to cold damage from winter injury (12). Significant tree losses have occurred in the midwest United States when environmental conditions are conducive to fireblight development (8, 17, 18). Thus, it is essential to continue to test new rootstock selections for their survivability and performance in areas where significant losses have occurred.

In 1986, TRECO nursery made available trees on a range of rootstocks that had limited or no testing in the United States. Trees with 'Delicious,' 'Golden Delicious,' and 'Granny Smith' scions were planted in Washington (1) and trees with scions of 'Lawspur,' 'Macspur' and 'Redchief' were planted in Ohio. Included in these plantings were 5 Vineland rootstock selections (V.) that originated as open-pollinated seedlings of M.9 and 'Kerr' crabapple, which is very hardy (3). Several selections from the Polish (P.) apple rootstock breeding program were selected for tree size control and efficient production under conditions of severe winter cold. Selections from the Michigan Apple Clone (MAC.) series and standards from the East Malling (M.) programs were also included.

Materials and Methods

The trees were planted in May 1986 in a clay loam (Ross moyne-bonnell) soil at The Ohio State University Southern Branch near Ripley, Ohio. The trees were spaced 6′ x 16′ (1.8 m x 4.9m) in a randomized block design with rows maintained as single cultivars. There were 10 single replicate trees of 'Macspur McIntosh' and 'Lawspur Rome Beauty' and 5 replicate trees of 'Redchief Delicious.' The trees

Salaries and research support provided by state and federal funds appropriated to the Ohio Agricultural Research and Development Center, The Ohio State University, Journal Article No. 21-95.

[1]The Ohio State University.
[2]Hort and Food Research Institute of New Zealand.

Appreciation is extended to TRECO, 10906 Monitor-McKee Rd., Woodburn, Oregon 97071 for donation of the trees for this study and to IDFTA and OFGS for financial support.

were supported on a 3-wire trellis by tying the leader to the wires. The trees were minimally pruned and trained to a conic or pyramidal shape. Both chemical and hand-thinning were used to encourage annual cropping and insect and disease control used recommended materials. Tree size and yield were recorded annually. After 4 growing seasons (1989), root suckers/tree were counted and the development of internal bark necrosis (IBN) was rated as 1 = no internal bark necrosis, 5 = bark cracks to 10 = trees dead from IBN. At Bloom in 1991, 1992 and 1993, four two-year-old shoots per 'McIntosh' tree were selected from trees on 11 rootstocks and the following measurements taken: length, number of flowering spurs, number of non-flowering spurs and number of shoots (vegetative growth longer than 5 cm). Biennial bearing was assessed using the index developed by Hoblyn et al. (14).

Results and Discussion

A severe epidemic of fireblight occurred in this orchard in 1989 and 1990 causing significant tree loss (Table 1). Tree loss in subsequent years was minimal and most of the loss occurred on 'Macspur' (22% loss) and 'Lawspur' (24% loss) the cultivars most susceptible to fireblight. 'Redchief' had only 12% loss over the 8 years and in other epidemic fireblight years 'Delicious' had minimal tree losses (8). Considerable variation occurred among rootstocks with minimal or no losses occurring on the following rootstocks: OAR1, V.4, V.7, M.7EMLA, P.1, V.1 and CG.10. The following rootstocks had unacceptable losses of more than 30% on both 'Macspur' and 'Lawspur': M.26EMLA, MAC.9, P.22, C.6, M.9-EMLA, P.16. Mark and M.9 had unacceptable losses with 'Macspur,' but minimal loss with 'Lawspur.' The re-

Table 1. Survival, rootsuckers and internal bark necrosis (IBN) developing on three apple cultivars on 22 rootstocks in Ohio.

	Macspur McIntosh			Lawspur Rome Beauty			Redchief Delicious		
Rootstocks	survival %	suckers** %	IBN*	survival %	suckers %	IBN	survival %	suckers %	IBN
Mark	60	75	3.0	100	0	1.5	80	80	4.2
M.27EMLA	100	0	2.3	33	20	2.4	--	--	--
B.146	85	33	3.0	50	0	1.5	--	--	--
P.22	12	50	2.7	54	0	1.2	83	40	5.3
MAC.9	10	87	2.7	55	14	1.4	85	71	4.2
P.16	66	25	3.7	--	--	--	50	80	4.8
B.9	100	10	2.8	--	--	--	--	--	--
V.3	88	0	3.4	50	0	1.0	--	--	--
P.2	100	33	2.4	40	0	2.0	100	0	4.6
M.9	64	18	2.6	100	0	1.4	75	86	4.4
CG.10	80	22	3.2	100	20	1.4	100	14	4.5
MAC.39	80	20	2.8	40	20	1.5	83	16	4.8
M.9EMLA	69	0	2.8	63	0	1.5	100	16	4.8
C6	60	11	2.7	72	0	1.2	100	20	4.8
V.1	88	22	2.8	80	12	1.2	100	14	4.1
M.26EMLA	33	25	3.2	45	0	1.4	80	25	5.0
V.2	100	30	2.9	66	0	1.0	85	0	5.0
P.1	91	30	2.7	100	0	1.1	100	25	4.0
M.7EMLA	90	50	3.1	91	30	1.5	100	100	4.6
V.7	100	10	2.9	100	0	1.1	80	25	5.0
V.4	100	80	2.9	100	18	1.0	100	100	4.4
OAR1	100	40	3.1	100	10	1.2	--	--	--

*IBN Rating = 1 no internal bark necrosis, 5 bark cracks to 10 tree dead. IBN were rated in October 1989.
**Percentage of trees with some root suckers.

Table 2. Influence of 22 rootstocks on tree size, growth rate and cumulative yield and yield efficiency of 'Macspur McIntosh' apple trees over 8 years.

Rootstock	TCA cm²	Height m	Spread m	Change in TCA* early	late	late/early	Average** bienniality index	Cumulative Yield/tree kg	Efficiency kg/cm²
Mark	14.0	2.12	1.70	3.0	4.4	1.75	.53	37.1	2.73
M.27EMLA	15.0	2.11	1.67	3.3	4.2	1.42	.49	41.2	2.56
B.146	16.1	2.35	1.81	4.3	6.0	.57	.56	40.0	2.49
P.22	17.3	1.85	2.25	5.0	7.9	1.22	.34	73.0	3.24
MAC.9	17.7	2.03	1.76	4.1	4.5	.84	.46	37.1	2.36
P.16	19.0	2.10	2.36	3.8	5.5	.63	.54	51.4	2.47
B.9	34.3	2.70	2.34	10.3	9.8	.94	.46	95.1	2.74
V.3	52.3	3.02	2.78	11.8	25.1	2.14	.59	132.2	2.55
P.2	52.5	2.81	2.78	15.1	18.9	1.23	.49	127.9	2.25
M.9	53.7	3.90	2.74	14.5	24.1	1.77	.63	111.6	2.30
CG.10	54.5	3.32	2.68	11.1	27.8	2.59	.75	129.7	2.38
MAC.39	60.7	3.37	2.80	15.1	28.4	2.06	.65	125.9	2.46
M.9EMLA	68.4	3.22	2.88	19.3	32.6	1.66	.55	150.2	2.10
C6	69.8	3.36	2.86	15.9	30.5	1.79	.55	123.8	1.79
V.1	75.5	3.44	2.97	18.3	39.2	2.08	.64	146.6	2.06
M.26EMLA	104.3	3.83	3.46	21.3	49.5	1.80	.60	136.9	1.36
V.2	112.7	3.69	3.41	24.7	59.0	2.30	.64	167.6	1.51
P.1	131.8	3.61	3.42	22.6	76.4	3.90	.57	140.7	1.42
M.7EMLA	136.5	3.90	3.36	28.3	88.2	3.20	.61	141.9	1.00
V.7	144.2	3.90	3.69	31.2	79.8	2.65	.65	210.0	1.50
V.4	157.3	3.70	3.61	35.2	86.6	2.31	.63	186.4	1.36
OAR1	202.8	4.02	3.71	36.0	125.9	3.59	.54	.67.7	.32
LSD .05	23.4	.36	.42	5.5	17.8	1.43	.09	41.9	.52

*Change in TCA — Early 1989-1987 and Late 1993-1990.
**Bienniality index: 0 = regular bearing to 1 = extremely biennial.

verse pattern existed with M.27EMLA, B.146, V.3, P.2, MAC.39 and V.2.

Production of root suckers also varied by cultivar, for example, a high percentage of the trees on Mark and MAC.9 produced rootsuckers with 'Macspur' and 'Redchief' and relatively few when 'Lawspur' was the scion. The following rootstocks tended to be non-suckering: M.27EMLA, B.9, V.3, M.9EMLA, C6, V.7. A high percentage of trees on the following rootstocks produced suckers on at least one cultivar: Mark, MAC.9, P.16, M.9, M.7-EMLA, and V.4.

Internal bark necrosis or measles is due to manganese toxicity and generally is most prevalent on 'Delicious,' particularly following years of drought (6). In 1988, Ohio experienced the driest spring on record with accumulated rainfall from April through June only 44% of normal (7, 19). IBN was noticeable on the 'Redchief' trees in 1989 being most severe on trees on P.22, M.26EMLA, V.2 and V.7 (Table 1). All 'Redchief' trees had some symptoms. Almost no symptoms appeared on 'Lawspur,' while 'Macspur' had minor symptoms being most obvious on trees on P.16, V.3, CG.10, M.26-EMLA, M.7EMLA and OAR1.

An overall comparison of the three cultivars (data not presented) indicated that 'Macspur' trees were the largest and consistently had the greatest increase in TCA while 'Redchief' trees were the smallest and made the slowest change in TCA with 'Lawspur' intermediate. 'Redchief' was the most biennial and 'Lawspur' the least with 'Macspur' intermediate. 'Lawspur' trees

Table 3. Influence of 20 rootstocks on tree size, growth rate and cumulative yield and yield efficiency of 'Lawspur Rome Beauty' apple trees over 8 years.

Rootstock	TCA cm²	Height m	Spread m	Change in TCA* early	Change in TCA* late	Change in TCA* late/early	Average** bienniality index	Cumulative Yield/tree kg	Cumulative Efficiency kg/cm²
V.3	8.0	1.80	1.40	2.1	2.3	1.15	.45	20.6	2.58
M.27EMLA	13.2	1.93	1.90	2.5	4.6	1.66	.63	24.1	1.82
V.2	16.0	2.00	1.90	4.1	7.1	1.51	.38	44.0	2.27
MAC.9	18.1	2.14	1.78	3.4	4.1	1.41	.39	60.3	3.27
B.146	20.0	2.20	2.10	2.8	9.6	3.38	.21	79.8	3.97
P.22	20.8	2.53	1.83	6.7	5.8	.98	.27	73.3	3.72
V.1	22.9	2.37	2.00	4.9	10.2	1.95	.30	106.3	4.47
P.2	25.5	2.35	2.30	5.0	10.1	1.90	.21	99.5	3.81
Mark	25.6	2.62	2.12	3.7	9.5	2.43	.28	110.9	4.08
V.7	35.2	2.98	2.40	7.6	19.1	2.74	.37	96.5	2.52
M.9	35.3	3.04	2.37	7.7	16.9	2.19	.29	132.9	3.76
CG.10	45.3	3.28	2.41	9.4	24.1	2.53	.29	180.3	4.25
M.9EMLA	45.7	3.20	2.50	12.2	21.7	1.83	.31	172.3	3.71
C6	46.5	3.22	2.42	10.6	23.6	2.54	.22	169.0	3.72
M.26EMLA	54.4	3.24	2.46	11.7	24.5	2.07	.31	196.2	3.51
M.7EMLA	55.4	3.41	2.52	10.6	29.5	2.76	.36	111.0	2.10
MAC.39	55.8	3.57	3.02	10.7	27.8	2.34	.25	217.4	3.92
P.1	64.9	3.14	2.71	13.3	35.2	2.68	.33	146.8	2.37
V.4	74.8	3.27	2.63	16.9	39.8	2.39	.32	123.6	1.59
OAR1	116.7	3.81	2.95	27.2	67.6	2.53	.28	191.0	1.63
LSD .05	23.4	.36	.42	5.5	17.8	1.43	.09	41.9	.52

*Change in TCA — Early 1989-1987 and Late 1993-1990.
**Bienniality index: 0 = regular bearing to 1 = extremely biennial.

were the most productive and had the greatest yield efficiency of the three cultivars in this trial. 'Macspur' had higher cumulative yields than 'Redchief,' but the reverse was true in yield efficiency (yield ÷ trunk area).

'Macspur' trees on the following rootstocks were very similar in size to M.27EMLA: Mark, B.146, P.22, MAC.9 and P.16 (Table 2). The following were very similar in size to M.9: B.9, V.3, P.2, CG.10, MAC.39, M.9EMLA, C6 and V.1. Trees on V.2 were very similar in size to M.26, while P.1, V.7 and V.4 were similar to M.7EMLA with OAR1 producing the largest trees. The rootstocks in this trial produced a continuum of tree sizes and considerable overlap existed between these general groupings. Generally, trees within a grouping could be managed in a similar spacing and training system, while changes would be required between the size groupings.

Relative growth rate was evaluated by comparing the change in TCA early (1989-1987) and late (1993-1990) in the 8 years of this trial. Trees on B.146, MAC.9, P.16 and B.9 made more rapid growth early compared with the later growth rates. Trees on P.1, M.7-EMLA and OAR1 made particularly rapid growth in the later years. Trees on P.22 had a very low biennial tendency, while trees on CG.10 were very biennial. Trees on most rootstocks were not different from the average biennially index of .56 for all trees of 'Macspur.'

'Macspur' trees on V.7 had the highest cumulative yield/tree with trees on V.4 and V.2 being not significantly different in yields or efficiencies. Large trees generally had higher yields, ex-

Table 4. Influence of 17 rootstocks on tree size, growth rate, and cumulative yield and yield efficiency of 'Redchief Delicious' apple trees over 8 years.

Rootstock	TCA cm²	Height m	Spread m	Change in TCA° early	late	late/early	Average°° bienniality index	Cumulative Yield/ tree kg	Efficiency kg/cm²
MAC.9	14.1	1.80	1.61	3.1	2.9	1.04	.57	45.4	3.01
P.22	15.0	1.80	1.50	2.9	6.7	1.90	.66	43.6	3.01
Mark	15.6	1.64	1.52	2.4	4.6	1.47	.49	51.8	3.11
P.2	17.2	1.72	1.98	3.4	1.5	1.02	.68	57.5	3.41
CG.10	23.4	2.86	2.00	4.0	10.6	3.04	.82	69.3	2.93
M.9	27.3	2.70	2.43	5.2	4.0	.42	.75	71.8	2.58
V.1	30.4	2.64	2.22	6.3	11.1	2.16	.57	88.2	2.73
M.9EMLA	33.3	3.08	2.53	7.9	9.5	1.29	.56	87.7	2.69
MAC.39	33.9	3.00	2.88	7.4	8.7	.55	.70	68.2	2.07
O.3	38.8	3.05	2.55	7.9	7.4	.34	.70	98.2	2.43
C6	41.7	3.08	2.50	8.0	20.8	2.57	.68	100.1	2.52
V.2	47.4	3.16	2.60	10.0	25.3	2.41	.72	141.1	2.53
M.26EMLA	48.3	3.02	2.82	9.0	25.0	2.26	.60	80.5	2.18
M.7EMLA	50.4	3.63	2.30	12.2	22.0	1.49	.72	77.0	1.63
P.1	58.4	3.42	2.62	12.3	31.3	2.56	.63	83.2	1.60
V.4	63.7	3.18	2.36	14.8	30.3	2.05	.75	115.9	1.39
V.7	65.1	3.70	3.30	13.9	39.1	2.75	.69	154.4	2.31
LSD .05	17.9	.42	.44	5.1	19.1	2.7	.10	83.5	1.11

°Change in TCA = Early 1989-1987 and Late 1993-1990.
°°Bienniality index: 0 = regular bearing to 1 = extremely biennial.

cept for the largest trees, those on OAR1, which performed poorly. Trees on MAC.9 and Mark did not differ in cumulative yield, efficiency or any other character measured. Thus, earlier studies (5, 16) comparing MAC.9 to other rootstocks are likely valid evaluations of the virus-free Mark. In a previous trial trees on MAC.9 were closer to M.9 in size than to M.27 and in the companion planting in Washington (1), 'Granny Smith' and 'Delicious' trees were similar in size to M.9, while trees of 'Golden Delicious' trees were closer to M.27EMLA. 'Redchief' trees on M.9 and M.9EMLA had 46% and 33% larger TCA's in Ohio than in Washington, while 'Redchief' on Mark and MAC.9 were 21% and 5% larger in Ohio. Thus, there appears to be a cultivar and site interaction for tree size. The minimal pruning and heavy early cropping of the trees on Mark and MAC.9 trees in Ohio likely accounted for the relatively small tree size. All but one tree on Mark and MAC.9 had the gall-like swelling at and just beneath the soil surface which has been reported as a characteristic of these rootstocks (15). None of the trees on M.9 or M.9EMLA exhibited the swelling. Trees on all rootstocks smaller than V.1, except C6, were more efficient than M.7EMLA. Trees on OAR1 were particularly inefficient, which has been reported in previous studies (4, 16).

'Lawspur' trees on the following rootstocks were similar in size to trees on M.27EMLA: V.3, V.2, MAC.9, B.146, P.22, V.1, P.2 and Mark (Table 3). The following were similar in size to 'Lawspur'/M.9: V.7, CG.10, M.9E and C6. A third arbitrary group did not differ significantly in size from trees on M.7-EMLA: M.26EMLA, MAC.39, P.1 and V.4. Again, these groups overlapped in tree size developing nearly a continuum. There were several notable differences in relative size produced by a rootstock with the different cultivars. V.2 produced 'Macspur' and 'Redchief'

Table 5. Influence of 11 size-controlling rootstocks on the morphological development on two-year-old wood of 'Macspur McIntosh.'

Rootstocks (smallest-largest)	1991				1992				1993			
	Shoot length cm	Flower spurs	Non-flowering spurs	Non-flowering shoots	Shoot length cm	Flower spurs	Non-flowering spurs	Non-flowering shoots	Shoot length cm	Flower spurs	Non-flowering spurs	Non-flowering shoots
Mark	19.6e	4.4cd	.2d	1.66cde	19.0e	.4d	4.1d	.2c	16.2f	2.7c	3.5de	.1d
M.27EMLA	20.5e	4.8bcd	.4d	1.45de	22.5de	.8d	4.1d	.4bc	19.5ef	3.2bc	3.2e	.2cd
MAC.9	19.4e	4.5cd	.8cd	.60e	18.8e	1.1bcd	4.3d	.4bc	21.3ef	3.2bc	3.3e	.2cd
B.9	31.2de	7.2abc	.2d	3.10bcd	24.7cde	2.6ab	5.4cd	.4bc	22.6def	4.3abc	4.1cde	.4bcd
M.9	43.6cd	8.6a	.9cd	3.60abc	31.9abc	1.7abcd	7.2bc	.8abc	32.3bc	6.8a	7.0b	.7bcd
MAC.39	48.6bc	7.7abc	2.4bcd	3.7abc	29.1bcd	.7d	6.8bc	.3c	25.3cde	4.9abc	4.8bcde	.5bcd
V.1	44.8cd	8.0ab	1.8cd	4.0ab	28.9bcd	2.2abcd	7.4bc	.4bc	30.7bc	6.1a	6.0bc	1.0b
M.26EMLA	51.9bc	10.0a	2.0bcd	5.5a	33.2ab	2.5ab	8.9ab	.5abc	30.7bc	4.5abc	4.5cde	.9bc
M.7EMLA	62.6ab	7.6abc	4.9b	4.2ab	34.1ab	3.4a	7.6bc	.9ab	33.8b	5.4ab	6.0bc	.8bc
V.4	61.3ab	9.8a	3.7bc	4.0ab	28.7bcd	1.9abcd	7.7bc	.4bc	29.3bcd	5.1abc	5.8cd	.4cd
OAR1	73.2	1.6d	16.1a	2.6bcde	27.9a	1.06cd	10.7a	1.0a	47.2a	3.0bc	10.1a	1.8a

Mean separation in columns by Duncan'S Multiple Range Test, P = .05.

trees similar in size to those on M.26-EMLA while with 'Lawspur' trees on V.2 were much smaller, similar in size to trees on M.27EMLA. In the companion study in Washington (1), trees on V.2 were between M.26EMLA and M.7A in size for all three cultivars. Thus, the very small size with 'Lawspur' on V.2 may be a partial incompatibility with this cultivar. Likewise, 'Lawspur' on V.1 was only 42% the size of' trees on M.26EMLA, while 'Redchief' on V.1 were 63% and 'Macspur' on V.1 were 72% the size of trees on M.26EMLA. Trees of all cultivars were slightly larger on V.4 than M.7EMLA while those on V.7 tended to be smaller ('Lawspur'), comparable ('Macspur') or larger ('Redchief') than similar trees on M.7EMLA. These differences in relative ranking are somewhat unusual in rootstock trials and further studies will be necessary to clearly determine the size of trees particularly with the Vineland series across a range of cultivars.

'Lawspur' trees on OAR1 grew much faster than trees on any of the other rootstocks, and had one of the lowest cumulative yields relative to tree size (Table 3). Trees on B.146 grew very rapidly in the later years, relative to others in their size class. Generally, as tree size increased, yield/tree increased, trees of 'Lawspur' on V.7 and M.7EMLA were noteworthy in breaking this pattern, as with P.1 and V.4. The lowest yield efficiencies in each of the 3 arbitrary size groups were on M.27EMLA, V.2 and V.3 for the smallest trees, V.7 for trees of intermediate size and V.4, M.7EMLA and P.1 for the largest trees. Conversely, the best performers in each size class were V.1, CG.10 and MAC.39 for small, medium and large size trees, respectively. These differences however, represent trends only and were not statistically significant.

'Redchief' trees on the following rootstocks were similar in size to trees on M.7EMLA: V.2, M.26EMLA, P.1, V.4 and V.7 (Table 4). The following rootstocks produced 'Redchief' trees similar in size to trees on M.9: CG.10, M.9, V.1, M.9EMLA, MAC.9, and C6. Although M.27 was not present the following would likely be similar in size to trees on this rootstock: MAC.9, P.22, Mark, P.2. Trees on the following rootstocks had relatively high biennialty indices on both 'Macspur' and 'Redchief,' the most biennial cultivars in this trial: CG.10, M.9, MAC.39, V.2, V.4, V.7, M.7EMLA. However, overall it was not possible to classify all rootstocks according to their propensity for biennial bearing since the bienniality index depended on the interaction between rootstock and cultivar. For example, 'Macspur' and 'Redchief' trees on M.9, CG.10 and MAC.39 had relatively high bienniality indices whereas, 'Lawspur' trees on these rootstocks had lower than average indices.

Generally, yield increased with increasing tree size, but tree size only accounted for about half the variation in yield per tree. Higher yield efficiencies were obtained by smaller trees for both 'Macspur' and 'Redchief,' but no such trend was evident for 'Lawspur' trees. Other studies have also found more dwarfing trees to be more efficient (12, 13) and 'Lawspur' to be very efficient cultivar that does not follow trends of other cultivars (10).

A correlation analysis was conducted on the 16 rootstocks that were common with all three cultivars in an effort to determine the value of early TCA or cumulative yield data in predicting year 8 results. Final tree size could be predicted after year 4 with a coefficient of determination above 0.94, but cumulative yield was poorly predicted until year 6 when $r^2 = 0.88$ occurred. The influence of rootstocks on tree size at the end of year four was closer between 'Macspur' and 'Redchief' (r = .83) and 'Lawspur' and 'Redchief' (r = .80) than between 'Macspur' and 'Lawspur' (r = .73). At the conclusion of the eighth growing season this relationship was slightly better ('Macspur'-'Redchief' r = .85; 'Macspur'-'Lawspur' r = .83; 'Lawspur'-'Redchief' r = .90). The same analysis on cumulative yield showed very little association through 8 years.

Two-year-old 'Macspur' shoots on OAR1 tended to be the longest all three years they were measured and generally had the greatest number of non-flowering spurs and the most shoots in 1992 and 1993 (Table 5). Mark, M.27EMLA and MAC.9 tended to have the shortest shoots and fewest non-flowering spurs and vegetative shoots among he 11 rootstocks studied. The proportion of spurs bearing flowers varied with year, with high proportions of flowering spurs in 1991, low proportions in 1992 and an intermediate degree of flowering in 1993. In 1991, the rootstocks with the highest degree of flowering were B.9, Mark, M.27EMLA and M.9 whereas, in 1992 B.9 and M.7EMLA had the highest degree of flower development. Except for OAR.1, which had the lowest degree of flowering in each of the 3 years, rootstock had little effect on flowering in 1993. The number of flower clusters per meter of branch length was more closely related to the proportion off flowering spurs (r^2 = 0.93, 0.96 and 0.75 for 1991, 1992 and 1993, respectively) than the number of spurs per meter. Similar results have been obtained previously for spur-type 'Delicious' (13).

In considering the overall performance of these rootstocks compared to the Malling rootstock that produces a similar sized tree, none are significantly better. In the M.7 size class, P.1, V.4 and V.7 had good survival and equalled M.7 in production and efficiency. In the M.26 size class, V.2 survived better and had equivalent productivity. In the M.9 size class, V.1, V.3, CG.10, P.2, B.9 and MAC.39 were similar in survival and productivity. In the M.27 size class, although P.22 was productive, it experienced significant tree loss. A number of the rootstocks in this trial of equivalent survival and productivity to their Malling counterpart, may have more winter hardiness or other attributes that make them desirable for further testing.

Literature Cited

1. Barritt, B. H., B. S. Konishi and M. A. Dilley. 1995. Performance of three apple cultivars with 23 dwarfing rootstocks during 8 seasons in Washington. Fruit Var. J. 49(3):158-170.
2. Cummins, J. N. and H. S. Aldwinckle. 1983. Rootstock breeding. Chapter, in *Methods in*

Fruit Breeding by J. N. Moore and J. Janick. Purdue Res. Foundation, West Lafayette, IN.
3. Elfving, D. C., I. Schecter and A. Hutchinson. 1993. The history of the Vineland (V.) apple rootstocks. Fruit Var. J.47(1):52-58.
4. Fallahi, E., M. N. Westwood, M. H. Chaplin and D. G. Richardson. 1984. Influence of rootstock and K and N fertilization on leaf mineral composition and yield in a high density orchard. J. Plant Nutr. 7:1161-1177.
5. Ferree, D. C. 1989. Early performance of MAC apple rootstocks in Ohio. Fruit Var. J. 43(3):102-105.
6. Ferree, D. C. and A. H. Thompson. 1970. Internal bark necrosis of the apple as influenced by calcium placement and soil manganese. Univ. of MD Agr. Exp. Sta. Bul. A-166.
7. Ferree, D. C. and J. C. Schmid. 1990. Performance of apple rootstock cultivars and cultural treatments under the stress of the 1988 drought. In Fruit Crops 1989: A Summary of Research. OARDC Res. Circ. 297:25-36.
8. Ferree, D. C., M. A. Ellis, and F. R. Hall. 1983. Tree loss due to fireblight infection of rootstocks and interstems in Ohio apple orchards. Compact Fruit Tree 16:116-120.
9. Ferree, D. C. and R. F. Carlson. 1987. Apple rootstocks--p. 107-142 Rom and Carlson (eds.) In *Rootstocks for Fruit Crops*. Wiley & Sons, New York.
10. Ferree, D. C. and W. T. Rhodus. 1993. Influence of mechanical hedging or root pruning on apple trees in intensive orchards. J. Amer. Soc. Hort. Sci. 118(6):707-713.
11. Forshey, C. G. and M. W. McKee. 1970. Production efficiency of a large and a small 'McIntosh' apple tree. HortScience 5(3): 164-165.
12. Hirst, P. M. and D. C. Ferree. 1995. Effect of rootstock and cultivar on the growth and precocity of young apple trees. Fruit Var. J. 49(1):34-41.
13. Hirst, P. M. and D. C. Ferree. 1995. Rootstock effects on shoot morphology and spur quality of 'Delicious' apple and relationship with precocity and productivity J. Amer. Soc. Hort.. Sci. (in press).
14. Hoblyn, T. J., N. H. Grubb, A. C. Ranter, and B. L. Wates. 1936. Studies in biennial bearing. J. Pomol. and Hort. Sci. 14:39-76.
15. NC140. 1991. Abnormalities in 'Starkspur Supreme Delicious' on nine rootstocks in the 1980-81 NC-140 Cooperative planting. Fruit Var. J. 45(4):213-219.
16. NC-140. 1991. Performance of 'Starkspur Supreme Delicious' on 9 rootstocks over 10 years in the NC-140 Cooperative planting. Fruit Var. J. 45(4):192-199.
17. Perry, R. L. 1992. The relative susceptibility of rootstocks to fireblight. Proc. Mich. St. Hort. Soc. 122:72-75.
18. Perry, R. L. and R. T. Fernandez. 1993. Apple rootstock studies in Michigan. Compact Fruit Tree 26:97-99.
19. Stevens, A. 1989. Will drought hit us again? The Ohio Farmer, Mar. 4:86-87.