Evaluation of Size-Controlling Apple Rootstocks for High-Density 'Gala' Apple Orchards in Arkansas: Final Year Results of the 1994 NC-140 Uniform Apple Rootstock Trial

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Summary. Growth and productivity of 'Gala' apple on 17 size-controlling rootstocks were studied in a 10-year trial in Arkansas as part of the NC-140 cooperative project. During the study, 70% of trees on the rootstocks 'Mark', M.27 E MLA, and Ott.3 died, while the overall survival average was 60%. Trunk cross-sectional area (TCSA) and height were largest on V.1 rootstock. 'Mark', M.27, and P.16 rootstocks produced the smallest trees. No significant difference was observed for tree performance among six M.9 clones for TCSA, shoot height, shoot spread, fruit yield efficiency, and fruit size. Nic.29, M.26, Pajam 1, Ott.3, and V.1 had significantly greater yields compared to other rootstocks. Trees on Nic.29 had significantly higher yields per tree compared to other M.9 clones. Nic29 and Pajam 1 were the largest M.9 clones with the greatest yields, and significantly more root suckers than other clones. No significant differences were observed for tree size between M.26 EMLA and M.9 EMLA. Fruit size was significantly smaller for M.27 EMLA and 'Mark' compared to all other rootstocks. Tree yield efficiency was significantly higher in M.9 and Ott.3 rootstocks. Cumulative yield was highest for B.9 and Ott.3. Cumulative yield was significantly correlated to tree size variables TCSA, shoot height, and spread estimated canopy volume and surface area. Cumulative yield was highly correlated with estimated canopy volume and surface area/volume ratio.

For Arkansas orchards to be economically sustainable, the system must be productive, both early in its life and annually, and easily manageable. Rootstocks, because of effects on orchard precocity, productivity, and size, have a profound influence on sustainability. Previous research at the University of Arkansas Agricultural Experiment Station has shown that high-density orchards in the range of 600-800 trees per acre maximize production and minimize labor using the central leader training systems such as vertical axis. Rootstock cultivars are important for the grower in developing specific tree characteristics for early production and good fruit quality. Therefore, it is important that rootstock varieties be tested locally for characteristics of survival, precocity, and fruit size. The objective of this long-term project was to test, in Arkansas conditions a range of size controlling rootstocks for high-density systems. Reported here are final results of the 10th season of the trial.

Materials and methods

A trial of 'Gala' apple on 17 size-controlling rootstocks was established at the University of Arkansas, Agricultural Experiment Station, Fayetteville, in 1994, as part of the NC140 uniform cooperative tree fruit research project (NC-140, Marini, 2001; Marini et al., 2000). The trial was also established at 24 additional North American locations in (19 states and 3 Canadian provinces). The Arkansas planting site consisted of Captina silt loam soil with a soil pH at planting of 5.5-5.8. Soil was deep-ripped and tree rows were cultivated prior to planting. 'K-31' fescue was planted in tree row middles. Tree spacing was 2.5 x 4.5m (8' x 15'). The vertical axis system was used to train each tree. A single wire trellis was 3m (9.5') was placed on each row. A single bamboo pole was attached at the wire and each tree trunk for support. Annual applications of residual and contact herbicides were used to maintain a 1.5m (5') strip under the trees in each row. Trees received supplemental trickle irrigation, annual applications of lime and fertilizer, and standard pest control management. Trees did not crop the first two seasons (1994, 1995), but were allowed to crop in following years.

Rootstocks used in the trial were representative of commercially available stocks which may be useful for high-density orchards. These included B.9, B.469, B.491, Ott.3, V.1, P.2, P.16, P.22, M.26 EMLA, M.27 EMLA, and 'Mark.' There were a number of M.9 clones including M.9 EMLA, Nic.29, Pajam 1, Pajam 2, NAKBT.337 (T.337), and Fl.56. Trees were measured annually for tree height, spread (average in-row and across-row), and trunk cross-sectional area (TCSA) at 25cm (10") above graft union. Beginning in the third season, fruit were harvested to determine total yield and average fruit size (25 fruit sample). Annual and cumulative yield efficiencies were calculated using total yield and TCSA. The trial was planted as a random complete block, blocked in two row blocks by orchard position (east to west), with 10 replications. All data were analyzed using SAS (Cary, NC) PROC GLM procedure, with mean separation by LSD if significant at the 0.05 level.

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Results and discussion

Weather and Survivability. In some years, weather had a significant impact on this trial. A record cold temperature in March 1996 resulted in bud damage and lighter bloom than anticipated. A bloom-time frost in April 1997 resulted in moderate to poor fruit set and no fruit thinning was required. Warm spring conditions in 1998 resulted in flowering one week earlier than normal. Severe heat and drought followed from July-September. Subsequently, sunburn and summer rots on fruit were prevalent in 1998. A bloom-time frost occurred in 2000 followed by near record precipitation during May-June. Trees showed some flood stress during this period. However, this was followed by severe drought and heat during July-September resulting in sunburn and severe summer fruit rots which limited cropping. In 2002, bloom and post bloom conditions were cool and wet. A frost occurred during bloom followed by severe infection by fire blight which limited tree growth and cropping. In 2003, a frost limited cropping and no fruit thinning was practiced. Survival and growth was not good in this trial over the 10-year period.

Over the 10-year period survival was less than 60% due to the following conditions: poor site and soil (result of fuel-oil tainted ground), lightening strike (1996), and strong winds that broke trees in several rows in two different seasons. However, some notable observations can be made. Trees on 'Mark', Ott.3, and P.16 had only 30% survival during the 10-year trial. Low survival of these three rootstocks during this 10-year trial is consistent with observations in other research trials at the University of Arkansas. Ott.3 appeared to die due to severe fire blight and other root rots. 'Mark', which is known for poor heat and drought tolerance, suffered during the seasons of severe drought and heat stress. Surviving trees were stunted and non-productive. Therefore, these rootstocks are cannot be recommended for this region. Fl.56 resulted in the best overall survivability followed by B.9, B.491, and Pajam 1 (Table 1). Trees on M.9 EMLA and its clones had average survival of approximately 70% which is better than average in this trial.

Growth. The largest trees based upon TCSA, shoot height and spread, were grown on rootstocks V.1, Ott.3, M.26 EMLA, Fl.56, Pajam 1, Pajam 2, T.337, and M.9 (Table 1). Trees on Fl.56, M.26, M.9, Nic.29, Ott.3, Pajam 1, Pajam 2, T.337, and V.1 were the tallest while trees on M.27 were the shortest (Table 1). Trees grown on M.26 were widest, and trees grown on M.27 were narrowest (Table 1). TCSA is a good measure of total aerial vegetative growth of a tree (Westwood, 1993). Pajam 1, V.1, and Nic.29 had the largest TCSA while trees grown on M.27 were smallest for TCSA (Table 1). Annual increase in TCSA was greatest for V.1 and Nic.29 and least for M.27 (Table 1). Root suckers occurred most on Nic.29 rootstock while all other rootstocks (not significant) had lower occurrence of root suckers. Generally, root suckering was not a problem in this trial.

Tree Cropping: Yield and Fruit Size. Trees exhibited biennial bearing pattern with larger yields in 1997, 1999, 2001, and 2003 than the years prior or succeeding. In 2000, yields were very light due to the large amount of sunburn, summer fruit rots, and early fruit drop due to the high temperatures experienced that year. Yields were suppressed in 2002 due to severe epidemic of fire blight and poor codling moth control. Tree yield was significantly correlated to TCSA and canopy volume/surface area ratio (data not shown). Trees on Nic.29, M.26, Pajam 1, Ott.3, and V.1 had the greatest yield (Table 1). Trees on P.22, Mark, M.27, B.469, and B.491 had the lowest yields (Table 1). The M.9 clones had similar yields, however, Nic.29, T.337, Pajam 1 and Pajam 2 had yields greater than M.9 EMLA. Trees on Fl.56 had yields less than M.9 EMLA (Table 1). Over the 10-year study, trees on V.1, Nic.29, and Pajam 1 had the greatest cumulative yields, while M.27 had the least cumulative yields (Table 1). Trees on B.9 produced a cumulative yield 35% less than trees on M.9 EMLA. M.9 clonal rootstocks Nic.29 and Pajam 1 had the largest cumulative yields per tree. This represents a significant production potential for these rootstocks. Fruit size was largest on M.26 EMLA, Nic.29, Pajam 1, and Pajam 2 (Table 1). Trees on P.16 produced large fruit but had a large annual variation and small yields.

Yield efficiency (Yield/TCSA) compares the amount of fruit relative to the amount of vegetative growth of the tree (Westwood, 1993) and is an indicator of physiological partitioning efficiency. Over the 10-year study, cumulative yield efficiency was highest for Nic.29 while 'Mark' and Fl.56 had the lowest cumulative yield efficiency (Table 1). Trees on 'Mark' were relatively non-productive while trees on Fl.56 grew vigorously and partitioned more resources into vegetative growth. Cumulative yield efficiency was highest for B.9 and Ott.3 (Table 1). There was little difference observed among the M.9 clones for yield efficiency (Table 1).

Conclusion

Most rootstocks included in this study are useful in high-density orchards for this region. Potential rootstocks and planting densities are recommended in Table 2. M.26 EMLA and M.9 EMLA are recommended for moderate density orchards. Trees on M.9 EMLA can be planted up to a density of 800 trees per acre. Higher density orchards trained to a vertical axis system will require rootstocks such as B.9, B.469, and P.22. M.9 EMLA is adaptable in other regions of the country for super-spindle, high-density plantings of 1500-3000 trees per acre. However, this high density planting system has not been studied in this region and is not recommended at this time.

Literature cited

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Table 1. Summary of 10 years growth and production of 'Gala' apple on 17 dwarfing rootstocks in the 1994 NC-140 Uniform Cooperative Trial, Fayetteville, Ark.,1994-2003. [z]

Rootstock	Survival %	Shoot height (m)	Shoot spread (m)	TCSA (cm^2)	2002-2003 Increase in TCSA (cm^2)	2003 Annual root suckers	2003 Total fruit yield (kg)	2003 Average fruit size (g)	2003 Fruit yield efficiency (kg/cm^2)	Cumulative fruit yield (kg)	Cumulative fruit yield efficiency (kg/cm^2)
B469	60	2.6 bc	1.99 efg	47.9 e	8.5 defg	0 b	24.5 f	121 de	0.52 cde	129 efg	2.7 abcd
B491	60	2.7 bc	2.41 def	48.1 e	9 cdefgh	0 b	22.4 f	149 abcde	0.53 cde	120 fg	2.9 abcd
B9	80	3.1 bc	2.26 def	52.4 de	6.4 gh	0.5 b	39.3 cdef	140 abcde	0.74 abcd	173 def	3.3 a
FL56	50	3.7 a	2.62 bcd	83 bc	13.8 bcdefg	1 ab	54.1 bcde	167 abcd	0.65 abcde	204 d	2.5 cd
M26	50	3.9 a	3.19 a	96.3 ab	15.5 abcdef	0.5 b	78.7 ab	180 a	0.85 ab	289 abc	3.1 abc
M27	60	1.8 d	1.36 h	23.4 f	3.7 h	0 b	15.9 f	143 abcde	0.73 abcd	59 h	2.6 bcd
M9	50	3.7 a	2.91 abc	89.1 ab	18.3 abcdef	0.4 b	66.4 bcd	135 abcde	0.75 abcd	268 bc	3.1 abc
Mark	30	2.6 bc	1.77 gh	46.6 e	7.1 fgh	0.1 b	17.3 f	126 cde	0.4 e	92 gh	2.2 d
NIC29	80	3.7 a	3.01 ab	106 a	22.9 a	1.8 a	98.9 a	110 e	0.94 a	340 a	3.2 ab
OTT3	30	4 a	2.96 abc	83.9 bc	16.6 abcd	0.7 b	76.6 ab	171 abc	0.91 a	283 bc	3.4 a
P16	40	2.3 cd	2.06 efg	35.6 ef	7.8 efgh	1 ab	29.3 ef	145 abcde	0.73 abcd	117 g	2.9 abc
P2	70	2.9 b	2.48 cde	67 cd	7.4 fgh	0.6 b	38.9 def	132 abcde	0.59 bcde	182 de	2.8 abcd
P22	50	2.6 bc	1.99 fg	44.4 e	5.6 gh	0.2 b	19.5 f	167 abcd	0.45 de	97 gh	2.6 bcd
PAJAM1	70	3.8 a	2.93 abc	101.4 a	17.6 abc	0.6 b	80.2 ab	153 abcde	0.8 abc	307 abc	3.1 abc
PAJAM2	70	3.7 a	2.95 abc	94.1 ab	16.3 abcde	0.4 b	69.3 b	152 abcde	0.72 abcd	277 bc	2.9 abc
T337	90	3.7 a	2 bcd	89.3 ab	16.3 abcde	0.9 ab	66.9 bc	129 bcde	0.75 abcd	262 c	2.9 abc
V1	50	3.9 a	2.97 ab	102.6 a	23.5 a	0.2 b	79.6 ab	177 ab	0.74 abcd	321 ab	2.9 abc

[z] Analysis using SAS GLM procedure. Means are least square means. Means separation by LSMEANS/PDIFF. Mean within a column followed by the same letter not significantly different (P = 0.05).

Table 2. Approximate planting density, spacing, and their appropriate apple rootstocks for use in high-density vertical axis planting in Arkansas.

Trees/acre	500-700	600-800	800-1000	1000-1200
Row spacing (ft)	15--10	12--8	8--10	8--10
Tree spacing (ft)	6	6--5	5--4	4--3
Rootstocks recommended	M.26 EMLA	Pajam 1	P.2	P.22
	Ott.3	M.9 EMLA	P.16	Mark
	V.1	Fl.56	P.22	M.27
	M.9 EMLA	NAKBT.337	B.9	
	Nic.29	P.2	B.469	
	Pajam 1	B.9	NAKBT.337	
	Pajam 2	P.16		
	Fl.56	B.469		
	B.491	P.22		
	B.9			