24. Spangelo, L. P. S., J. B. Julien, H. N. Racicot and D. S. Blair. 1956. Breeding apples for resistance to scab. Can. J. Agric. Sci. 36:329-338.
25. Thomas, H. E. 1933. The quince-rust disease caused by *Gymnosporangium germinale*. Phytopathology 23:546-553.
26. Thomas, H. E. and W. D. Mills. 1929. Three rust diseases of the apple. Cornell Univ. Agric. Exp. Stn. Memoir 123. 21 pp.
27. Warner, J. 1986. Susceptibility of apple scab resistant cultivars to *Gymnosporangium juniperi-virginianae, G. clavipes* and *Botryosphaeria obtusa*. Can. Plant Dis. Surv. 66:27-30.
28. Williams, E. B., Jules Janick, F. H. Emerson, D. F. Dayton, J. B. Mowry, L. F. Hough and C. H. Bailey. 1975. Co-op 12-18: Seven scab-resistant apple selections released for advance testing. Co-op Agric. Exp. Stn. Purdue Univ., Univ. of Ill. and Rutgers Univ. Bull. 69. 5 pp.
29. Williams, E. B., Jules Janick, F. H. Emerson, D. F. Dayton, J. B. Mowry, L. F. Hough and C. H. Bailey. 1975. "Sir Prize" apple. HortScience 10:281-282.
30. Williams, E. B., Jules Janick, F. H. Emerson, D. F. Dayton, L. F. Hough and Catherine Bailey. 1981. "Redfree" apple. HortScience 16:798-799.

Fruit Varieties Journal 44(4):225-235 1990

Early Performance of 'Starkspur Supreme Delicious' on 16 Rootstocks in the NC-140 Cooperative Planting[1]

NC-140

Abstract

In 1984 trees of 'Starkspur Supreme Delicious' apple (*Malus domestica* Borkh) on 16 rootstocks were planted at 30 sites in North America according to guidelines established for cooperative testing by the North Central Regional Cooperative Project (NC-140). After 5 years, 17% of the trees on P.22 had died, but tree loss on all other rootstocks except, MAC.39 and P.2, was below 10%. Seedling rootstocks produced the greatest number of root suckers with minimal suckering on other rootstocks. Based on trunk cross-sectional area, trees on the following rootstocks were similar to trees on seedling in size: P.18, A.313, B.490, M.4 and MAC.1. Trees on CG.24 and P.1 were between M.7 EMLA and seedling in size. The following rootstocks produced smaller trees than M.26: B.9, MAC.39, P.22, P.2, P.16 and C6. B.9, C6, P.16, P.22, P.2 and M.26 EMLA induced fruiting, while trees on seedling, MAC.1, A.313, and CG.24 lacked precocity. Variation in performance of these rootstocks across the 30 sites was considerable and demonstrates the importance of cooperative testing.

The commercially available apple rootstocks do not always perform well in the diversity of locations where apples are commercially grown. Problems associated with disease susceptibility and tolerance to environmental extremes of the rootstocks have been summarized in recent reviews (1, 4). Since dwarfing rootstocks represent one of the few options to increase production efficiency of the tree as much as 50-60%, the search for improved rootstocks has continued and is supported by several breeding programs (1, 2, 7). Although several attempts have been made to predict rootstock performance under controlled conditions, the only proven method has been field trials at a number of representative sites. In 1967 a

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. 175-90.

[1]Cooperators and locations shown in Table 1. Appreciation is extended to Oregon Rootstock and Tree Company, Inc., Woodburn, Oregon 97071 for propagating and furnishing trees for the planting and the International Dwarf Fruit Tree Association for shipping expenses. Special thanks are extended to Bert Bishop, The Ohio State University, for performing the statistical analysis of the data.

group of researchers from various states established the North Central Regional Committee (NC-140) to test new rootstocks in a coordinated and uniform series of field trials (5).

Results of earlier NC-140 apple interstem and rootstock trials have been published (3, 6, 8). The test plantings, from which results are reported here, were established in 1984 to compare the performance of a common scion on 16 different rootstocks in 30 apple producing areas in North America (Table 1). The committee recognizes that 5 years is not sufficient time to evaluate new rootstocks, but since many of these clones have not been tested widely and are becoming available commercially, it seemed prudent to share early survival and performance information. Rootstocks compared in this trial originated from breeding or evaluation programs in England (M-Malling series), Michigan (MAC.-Michigan Apple Clone series), Missouri (C-Clark series), New York (CG.-Cornell/Geneva series), Poland (P. Polish series) and Russia (B. Budagovsky series) and represent a wide range of tree size control.

Materials and Methods

Trees for this planting were propagated by Oregon Rootstock and Tree Company, Inc., Woodburn, OR, using virus-free 'Starkspur Supreme Delicious,' a spur-type strain, as the scion with all rootstocks being free from known viruses. Ten pollinizer trees each of 'Macspur McIntosh'/M.26 and 'Starkspur Golden Delicious'/M.26 were included strategically in each planting. The trees were planted with 10 single-tree replications in a randomized complete-block design individually randomized for each site. Due to a shortage of trees on some rootstocks, 11 sites did not receive trees on B.490, P.2, P.16, P.18, C6 or A.313. The trees were spaced 3.5 m x 5.5 m with 5-7 cm of the rootstock exposed above the soil line. All trees were headed at 70 cm and were trained to a free standing central leader tree that was unsupported. Irrigation, pesticides, orchard floor management and fertilizers were applied according to local recommendations.

The following data were collected annually at each site and summarized at a central location: survival, trunk circumference, number of rootsuckers, tree height, tree spread, total yield/tree, average weight of 50 fruit and flower clusters/tree for the first 3 years only. Each site also submitted monthly air and soil temperature extremes, rainfall, and light values.

Results and Discussion

After 5 years, 17.1% of the trees on P.22 had died, but tree losses on all the other rootstocks except MAC.39 and P.2 was below 10% (Table 2). Although it was not possible to ascertain the reason for the loss of each tree, anchorage was one reported problem associated with trees on P.22 and P.16 and these trees should have been supported. Suckering on most of the rootstocks was minimal, with trees on seedling rootstocks producing the greatest number of root suckers. Trees on seedling rootstock not only had the highest number of root suckers per tree, but also the greatest variability within sites. Very few suckers were produced by trees on M.26, B.490, B.9, MAC.39, P.2, P.18, P.22 and C6 at any of the sites. Suckers present a significant commercial problem and previous cooperative studies identified certain rootstocks such as MAC.24 with unacceptable sucker production (6). None of the rootstocks in this trial suckered as extensively as trees on MAC.24. Most of the suckers were in close proximity of the trunk and not spread widely under the canopy as was the case with MAC.24.

Tree size as determined by trunk cross-sectional area (TCSA), indicated that trees on P.18, A.313, B.490, M.4 and MAC.1 were full size and compar-

Table 1. Locations and cooperators in the 1984 rootstock trials coordinated by NC-140.

Location		Cooperator	Planting Location
(AR)	Arkansas	Roy C. Rom	Fayetteville
(BRC)	British Columbia	Harvey A. Quamme	Summerland, Canada
(CA)	California	Warren C. Micke	Kearney
(CO)	Colorado	Kenneth C. Yu	Austin
(GA)	Georgia	Stephen C. Myers	Blairsville
(IL)	Illinois	Daniel B. Meador	Urbana
(IN)	Indiana	Richard Hayden	West Lafayette
(IA)	Iowa	Paul Domoto	Ames
(KS)	Kansas	Frank Morrison	Manhattan
(KY)	Kentucky	Gerald R. Brown	Princeton
(ME)	Maine	James R. Schupp	Monmouth
(MA)	Massachusetts	Wesley R. Autio	Belchertown
(MEX)	Mexico	Rafael A. Parra Quezada	Sierra de Chihuahua
(MI)	Michigan	Ronald L. Perry	Clarkesville
(MN)	Minnesota	Emily E. Hoover	St. Paul
(MO)	Missouri	Michele R. Warmund	New Franklin
(NJ)	New Jersey	Edward F. Durner	Cream Ridge
(NC)	North Carolina	Eric Young	Fletcher
(NOS)	Nova Scotia	Charles G. Embree	Kentville, Canada
(OH)	Ohio	David C. Ferree	Wooster
(ONT)	Ontario	Donald C. Elfving	Simcoe, Canada
(OR)	Oregon	Porter Lombard & Anita Miller	Corvallis
(PA)	Pennsylvania	Loren D. Tukey	University Park
(TN)	Tennessee	Charles C. Mullins	Crossville
(TX)	Texas	Jody W. Worthington	Stephenville
(UT)	Utah	David R. Walker	Farmington
(VA)	Virginia	John A. Barden	Blacksburg
(WA)	Washington	Bruce H. Barritt	Wenatchee
(WV)	West Virginia	Tara A. Baugher	Kearneysville
(WI)	Wisconsin	Teryl Roper	Sturgeon Bay

able to trees on seedling (Table 2). Trees on CG. 24 and P.1 were between M.7 and seedling in size. The following rootstocks produced trees smaller than M.26: B.9, MAC.39, P.22, P.2, P.16 and C6. Trees on P.16 and P.22 were very small, probably comparable to M.27 in size. Generally TCSA size relationships were reflected in tree height and spread measurements. Trees on the most vigorous rootstocks had filled 60% of their allotted space (3.5 m) at five years of age and obviously would require wider spacing than provided in this trial.

Tree size, as measured by trunk cross-sectional area (TCSA), was largest in KS, GA and CA (Table 3). These plantings are on very deep, fertile soils or with relatively long growing seasons. Average tree size was generally small in the following sites: ME, NJ, TN, PA, MA, WA, and WV. In WA the trial was located on a replant site that resulted in weak growth. Trees on M.4 were significantly larger (TCSA) than trees on seedling in CA, KS and OR and smaller at the following sites: MA, MI, MN, OH, ONT, TX, ME and MEX. The variation in

Table 2. Performance after 5 years of 'Starkspur Supreme Delicious' on 16 rootstocks planted in the 1984 NC-140 cooperative rootstock planting at 30 sites in North America.

Rootstock	Tree loss %	Root sucker (#/tree	1989 TCSA cm^2	Size Rel. to seedl. %	1989 Ht. (cm)	1989 Width (cm)	Flower clust. 1986 (#/tree)	1984-1989 Cumulative yield effic. (kg/ tree)	1984-1989 Cumulative yield effic. (kg/cm)
P.22	17.1	.6f*	8.1g	18	151l	101l	15.5abc	6.8	.92ab
P.16	9.2	1.2ef	9.2g	20	168i	124i	15.4abc	9.1	1.07a
P.2	10.3	.2f	12.6f	28	185h	145h	14.4abc	11.5	.95ab
B.9	6.4	.4f	18.1ef	40	216g	165g	23.6a	15.1	.91ab
MAC.39	10.0	.7f	18.0ef	40	231f	170g	7.4bc	11.4	1.04a
C6	6.0	.3f	23.9de	53	238f	190f	22.5ab	18.3	.77abc
M.26 EMLA	5.3	.4f	27.2d	61	258e	191f	13.3abc	17.5	.66abcd
M.7 EMLA	2.8	4.7b	34.0c	76	284d	206de	5.7bc	16.0	.45cde
P.1	3.2	1.3ef	37.5bc	84	287d	213bcd	9.6abc	18.1	.50bcde
CG.24	1.7	4.9b	39.0bc	87	292cd	201ef	4.2c	10.9	.29cde
MAC.1	2.1	2.9cd	40.6abc	91	289d	203def	2.7c	10.6	.25de
M.4	3.2	2.3de	42.3ab	95	301bc	217bc	4.9bc	15.4	.34cde
B.490	.1	.4f	42.9ab	96	308ab	223b	4.5bc	12.9	.27cde
SDL	3.2	8.7a	44.4ab	100	309ab	211cde	1.9c	9.9	.19e
A.313	2.1	3.8bc	47.6a	107	319a	243a	3.1c	14.1	.25cde
P.18	1.0	.5f	48.2a	108	319a	240a	4.4bc	16.3	.27cde

*Mean separation by Duncans Multiple Range Test, .05 level.

performance of these rootstocks across the 30 sites was considerable and is shown in tables 3-5. In sites that had the full compliment of rootstocks, CA had the highest coefficient of variation (C.V.) and MN and British Columbia the lowest (Table 3). Generally, in sites with partial compliments of trees, GA and KS had higher C.V.s than most others. The C.V. for M.4 across all sites was higher than the other rootstocks. It should be noted that trees on seedling rootstock were not more variable than trees on the clonal rootstocks. If an arbitrary range is established of 15% above or below the average TCSA across all sites, at no site do all rootstocks fall within this range and it only took a comparison of five rootstocks to eliminate them all. If this range is increased to 20% above or below the average TCSA, all sites were eliminated after comparing 11 rootstocks. Thus it is clear that no one site could provide adequate tree size information for the 30 locations tested. These few examples clearly show the advantage of testing new rootstocks in a coordinated manner so that extremes in performance can be identified and related to local environmental and soil conditions.

Canopy height measurements (Table 4) at 5 years of age indicate that trees on the following rootstocks could be managed entirely from the ground: B.9, P.22, P.2, P.16, and C6. Trees on these rootstocks also had shorter terminals and averaged a 21.4% increase in TCSA between 1987 and 1988. Since more vigorous rootstocks (P.18, seedling, CG.24, M.4, and A.313) averaged 42.2% increase in TCSA, it is obvious that the smaller rootstocks had slowed in growth and flowered early and would be the most suitable for intensive orchard systems utilizing more than 500 trees/acre. Trees on the more vigorous rootstocks would require short ladders to accomplish tasks in the tops

Table 3. Trunk cross-sectional area (cm^2) in 1988 of 'Starkspur Supreme Delicious' on 16 rootstocks planted in the 1984 NC-140 cooperative apple rootstock planting at 30 sites in North America.

Site	B.9	MAC.1	MAC.39	P.1	P.22	SDL	CG.24	M.4	M.7 EMLA	M.26 EMLA	B.490	P.2	P.16	P.18	C6	A.313	LSD .05	C.V.
AR	17.9	37.0	25.3	38.6	6.3	38.2	41.6	41.0	32.4	28.0	43.0	13.5	10.0	46.6	25.9	47.6	6.9	42.9
CA	11.6	59.0	20.6	45.4	7.5	81.9	31.4	103.5	38.8	35.2	72.8	11.1	8.9	105.7	21.5	92.0	13.3	74.2
GA	20.7	83.3	24.7	45.5	6.0	72.7	71.2	83.8	60.4	35.4							12.2	55.2
IL	16.8	58.5	25.7	47.3	8.1	56.0	31.9	55.9	41.2	44.2	52.9	11.6	7.2	55.9	24.0	55.5	15.2	51.2
IN	13.7	36.0	17.8	36.7	5.5	41.0	37.0	39.5	34.9	25.2	39.2	12.1	6.5	42.0	20.2	46.6	6.4	48.3
IA	19.7	48.8	20.9	40.0	7.0	53.3	44.9	48.7	36.4	31.7	47.3	13.5	9.8	51.3	24.3	49.1	5.8	46.9
KS	17.7	79.0	23.8	77.4	8.4	75.4	87.6	109.2	57.7	43.5							11.7	51.6
KY	20.7	41.8	25.0	31.9	6.9	41.3	45.0	43.8	35.4	37.4							8.0	36.9
MA	11.5	26.6	11.7	23.8	4.7	37.0	27.7	26.9	20.8	14.7	29.1	8.6	4.3	34.8	14.7	36.7	5.9	52.8
MI	16.9	47.1	18.7	42.5	7.6	52.7	27.7	46.6	36.3	30.8	43.5	11.1	8.8	51.9	27.0	51.3	5.6	49.6
MN	17.4	30.9	16.5	30.3	15.9	34.9	32.1	10.9	22.6	27.2	26.3	16.8	15.4	34.7	24.5	35.1	8.1	33.8
OH	23.6	54.0	25.0	45.4	8.9	68.4	52.7	45.3	46.3	36.6	60.0	14.7	11.8	54.4	32.1	57.5	7.9	46.4
OR	20.1	43.2	23.5	46.8	9.1	39.8	38.3	49.8	37.9	34.3	46.2	12.5	12.9	50.5	28.0	46.7	7.9	41.9
ONT	17.7	39.3	18.2	37.3	6.5	38.7	43.6	28.9	32.3	27.6							5.8	40.5
PA	15.5	28.9	11.6	23.0	5.6	28.8	22.8	24.3	22.2	21.9	25.2	8.8	5.0	29.2	17.1	24.7	6.4	41.1
VA	20.5	49.3	29.2	40.9	9.5	61.4	69.0	58.5	41.8	39.0	57.0	16.6	9.1	62.8	36.4	68.9	8.9	48.3
WA	13.0	32.5	11.0	30.4	5.4	32.7	26.3	34.6	30.1	12.3	30.8	8.9	6.2	39.3	14.6	33.0	4.9	51.9
WI	24.2	30.5	15.3	32.9	7.2	41.7	35.9	40.4	33.0	30.2	49.7	15.9	10.3	50.4	28.3	49.4	10.3	44.2
MO	21.1	47.3	15.2	38.2	8.2	46.2	59.0	46.8	39.9	30.2							8.4	45.8
UT	14.9	49.9	24.6	54.5	10.3	53.6	31.5	58.5	36.6	17.6	47.9	9.9	8.9	61.8	21.0	63.0	8.5	57.1
NC	13.2	30.5	15.3	25.0	14.6	39.7	34.7	35.6	32.7	25.8	40.3	14.0	6.1	43.4	22.3	41.4	7.0	43.5
TN	10.5	20.0	10.2	15.0	4.9	20.9	23.3	16.2	22.8	13.5							5.1	38.5
CO	17.7	35.1	16.3	37.9	6.8	41.8	39.5	38.9	29.4	25.6	30.9	12.1	11.6	38.9	24.1	38.5	5.1	42.0
BRC	18.6	40.5	19.9	37.7	13.6	43.7	44.6	42.6	28.8	28.7	45.8	20.9	15.4	44.0	35.6	44.2	7.9	35.8
NOS	17.3	43.4	11.6	37.1	5.1	35.2	34.8	30.9	31.6	24.6							3.8	45.0
NJ	8.5	26.8	10.7	25.6	4.9	26.7	28.5	21.1	21.1	16.3							5.3	44.5
TX	33.1	31.4	13.7	38.0	14.2	35.4	30.1	24.2	36.6	12.0							8.9	37.8
ME	11.9	14.7	7.2	21.4	3.1	19.4	19.3	3.9	19.2	12.4	27.5	6.0	6.7	18.4	12.5	22.1	3.4	51.5
WV	15.8	27.6	13.4	32.2	7.9	25.6	27.9	24.9	25.8	21.3							3.7	34.0
MEX	41.7	24.1	17.5	45.7	12.3	48.2	31.8	34.5	34.1	31.6							7.7	36.1
LSD .05 =	5.5	8.4	5.9	9.3	4.4	9.9	7.9	9.7	7.2	6.8	8.4	NS	5.4	11.1	6.6	11.4		
C.V.	36.1	38.3	32.0	31.3	39.7	35.2	39.6	55.5	28.4	33.7	29.6	27.7	34.5	36.8	27.6	33.6		

C.V. = Coefficient of Variation.

Table 4. Tree height (cm) after 5 years of 'Starkspur Supreme Delicious' on 16 rootstocks planted in the 1984 NC-140 cooperative apple rootstock planting at 30 sites in North America.

Site	B.9	MAC.1	MAC.39	P.1	P.22	SDL	CG.24	M.4	M.7 EMLA	M.26 EMLA	B.490	P.2	P.16	P.18	C6	A.313	LSD .05	C.V.
AR	232	306	293	306	170	332	332	321	303	322	320	212	208	336	291	336	25	18
CA	157	370	236	286	127	385	248	432	298	253	360	148	156	417	208	401	32	37
GA	237	394	275	308	130	392	412	420	339	299							43	28
IL	234	316	284	300	168	318	287	333	318	310	322	202	170	322	262	321	33	19
IN	199	290	229	282	117	307	305	301	284	228	298	176	130	302	225	295	30	25
IA	196	282	235	281	129	303	290	314	286	265	288	184	164	306	211	298	21	22
KS	212	337	274	344	161	353	352	364	309	279							22	22
KY	218	278	256	251	136	283	285	291	282	278							27	18
MA	231	292	250	295	143	323	303	310	288	245	309	193	163	315	240	328	25	21
MI	185	265	205	263	135	280	214	280	253	224	269	158	145	278	208	267	20	22
MN	233	265	228	268	218	271	260	200	249	263	236	215	211	262	242	259	30	9
OH	265	341	260	313	137	363	350	339	332	326	332	179	164	336	250	360	34	25
OR	221	349	282	348	160	356	335	355	331	310	354	192	197	366	235	374	24	24
ONT	211	286	240	287	149	301	311	273	266	267							21	18
PA	271	304	238	292	171	307	306	305	306	281	301	213	162	310	243	299	33	18
VA	253	356	320	327	177	386	389	385	346	319	368	232	182	387	301	398	33	22
WA	176	245	170	269	117	279	248	292	268	170	282	156	130	292	190	291	23	28
WI	202	230	195	241	120	269	260	266	257	234	274	168	140	275	213	290	28	22
MO	235	313	228	293	154	317	320	315	287	271							29	19
UT	190	290	227	309	142	311	252	318	260	184	299	157	145	313	198	315	20	27
NC	283	326	290	338	231	363	361	341	352	322	354	216	187	386	311	373	29	18
TN	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	--	--
CO	216	302	231	320	146	311	314	325	293	251	296	189	194	317	238	315	22	21
BRC	216	277	230	294	175	308	307	341	272	251	313	213	197	285	264	305	32	17
NOS	231	323	203	316	129	323	310	301	310	260							17	23
NJ	184	298	214	293	151	303	302	282	278	252							22	21
TX	236	241	145	260	191	256	251	235	281	163							40	19
ME	187	222	177	251	107	242	257	124	267	209	275	144	153	247	189	252	25	25
WV	261	327	293	339	188	339	346	341	343	313							23	16
MEX	286	227	201	281	170	288	241	259	275	262							26	15
LSD .05 =	29	23	28	29	30	23	25	22	23	28	21	38	35	26	41	29		
C.V.	23	23	25	21	27	22	24	27	21	25	11	14	15	14	15	14		

C.V. = Coefficient of Variation.

Table 5. Tree spread (cm) after 5 years of 'Starkspur Supreme Delicious' on 16 rootstocks planted in the 1984 NC-140 cooperative apple rootstock planting at 30 sites in North America.

Site	B.9	MAC.1	MAC.39	P.1	P.22	SDL	CG.24	M.4	M.7 EMLA	M.26 EMLA	B.490	P.2	P.16	P.18	C6	A.313	LSD .05	C.V.
AR	215	234	235	255	120	240	252	281	243	236	243	169	178	261	231	288	33	18
CA	134	380	242	287	112	394	250	451	335	265	384	146	133	439	189	445	44	42
GA	168	245	195	224	65	243	241	247	255	203							33	27
IL	178	216	213	235	100	226	211	268	221	227	229	136	109	242	192	246	44	24
IN	136	186	156	193	77	186	179	205	194	174	184	124	92	188	143	217	21	24
IA	149	206	167	203	77	204	199	221	200	181	185	137	125	215	168	210	19	22
KS	171	251	187	270	101	244	262	302	246	214							27	25
KY	159	203	176	198	95	203	198	215	206	216							27	19
MA	181	201	190	248	82	218	216	208	211	198	221	153	97	218	201	242	38	23
MI	256	225	172	244	103	221	190	240	212	186	211	126	126	228	174	215	25	22
MN	200	214	187	201	158	218	198	144	194	234	193	136	145	236	223	208	32	16
OH	226	258	237	252	131	269	244	269	274	255	246	158	145	265	208	282	41	20
OR	210	210	213	264	121	205	203	246	241	221	246	174	177	279	237	237	32	17
ONT	195	218	192	229	115	217	224	176	209	210							26	16
PA	182	206	170	207	72	215	212	208	216	179	221	110	87	218	172	199	35	26
VA	225	238	225	254	127	259	278	296	261	270	253	201	135	307	246	290	33	21
WA	165	213	137	223	89	216	190	235	225	156	201	125	106	239	162	244	27	27
WI	196	165	162	203	105	191	186	203	196	204	234	148	111	204	191	228	38	19
MO	131	179	143	179	75	189	178	192	178	151							22	22
UT	153	218	180	232	108	227	195	241	207	151	213	132	133	233	155	239	18	23
NC	181	210	187	219	146	237	215	237	218	223	210	162	118	239	230	247	36	17
TN	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	---	--	--
CO	123	162	119	174	74	174	162	175	160	131	153	104	93	167	139	190	22	23
BRC	163	201	161	225	125	215	219	228	208	186	234	170	133	208	197	235	32	17
NOS	174	212	154	214	94	185	207	197	210	192							20	20
NJ	130	194	155	201	72	195	195	203	181	175							25	24
TX	130	159	81	149	122	147	147	127	136	109							26	17
ME	146	144	108	180	50	154	171	76	182	139	192	104	78	168	150	173	24	30
WV	196	221	201	238	152	231	251	227	226	213							25	12
MEX	123	110	90	145	75	134	132	132	134	138							14	18
LSD .05 =	28	29	27	30	31	27	29	28	27	27	28	44	42	33	39	39		
C.V.	26	29	30	24	33	29	25	36	26	28	20	17	22	24	17	23		

C.V. =Coefficient of Variation.

Table 6. Number of flower clusters/tree on 'Starkspur Supreme Delicious' on 16 rootstocks planted in the 1984 NC-140 cooperative apple rootstock planting in their third year (1986).

Site	B.9	MAC.1	MAC.39	P.1	P.22	SDL	CG.24	M.4	M.7 EMLA	M.26 EMLA	B.490	P.2	P.16	P.18	C6	A.313	LSD .05
CA	75.4	21.7	36.1	73.9	64.0	18.4	54.5	38.4	43.5	55.0	24.0	64.9	64.5	48.3	90.6	38.7	30.6
GA	54.5	7.2	17.0	24.2	43.5	5.1	17.9	13.3	35.3	55.7							30.5
IA	26.6	0.0	0.8	0.1	25.6	0.4	0.0	0.2	0.5	7.4	0.1	18.4	8.2	0.0	17.8	0.0	7.3
KS	35.3	0.2	4.9	0.1	21.4	0.0	2.8	0.8	1.0	26.9							13.4
MA	58.2	4.5	26.9	40.9	27.1	8.9	3.5	6.3	11.6	25.1	8.7	20.7	21.6	4.7	37.7	5.7	24.5
MI	36.3	1.9	8.3	9.3	7.5	0.6	12.8	1.3	6.9	10.4	2.7	17.2	26.4	2.2	17.3	0.7	10.0
MN	10.7	2.2	1.3	0.0	7.8	0.0	3.2	5.8	0.1	1.8	1.5	7.5	6.8	0.3	7.6	0.0	5.9
NY	43.0	0.2	9.5	12.0	25.0	1.5	0.0	4.3	1.9	13.7	0.5	14.6	14.5	0.3	29.8	0.5	12.3
OR	6.2	0.0	0.2	0.0	37.6	0.0	0.6	0.0	0.0	0.7	0.0	9.3	21.5	0.0	11.5	0.0	16.3
QUE	7.7	0.4	1.9	0.5	7.0	0.0	0.1	0.0	0.2	4.9	0.8	6.2	5.3	0.0	4.4	0.0	3.5
VA	103.6	17.9	50.6	45.7	36.6	4.6	2.5	24.9	15.5	68.4	27.4	40.1	54.7	10.6	73.2	3.7	25.1
WA	11.1	0.0	6.3	0.2	12.1	0.0	0.5	0.0	1.6	15.2	0.0	7.1	9.6	0.2	7.1	0.0	15.6
WI	102.4	5.4	21.3	34.9	35.7	4.8	6.1	16.4	16.2	26.1	5.6	41.5	31.7	9.6	68.8	4.5	35.8
MO	16.6	1.8	8.5	10.2	14.5	2.2	0.9	7.3	7.4	13.2							7.3
UT	24.7	0.0	7.5	0.1	36.2	0.0	9.9	0.2	0.7	38.8	0.2	11.7	21.7	0.0	27.6	0.0	16.8
NC	26.4	7.3	10.5	31.2	24.7	8.0	5.0	15.5	20.9	23.5	18.2	16.7	24.8	10.9	35.7	9.7	14.6
TN	21.5	0.0	3.7	0.6	9.9	1.5	0.0	1.2	0.1	2.3	0.2	6.7	8.6	0.0	8.1	0.0	6.4
BRC	18.7	2.8	7.6	11.9	9.9	1.2	1.0	4.2	4.9	8.6	5.9	16.7	4.5	5.3	25.1	2.7	8.9
NJ	5.5	0.0	0.0	1.3	3.3	0.1	0.0	0.4	0.3							3.9	
ME	23.0	0.0	0.5	1.6	4.0	0.5	1.1	9.0	2.6	0.1	0.4	4.6	1.3	0.0	9.5	0.5	4.7
MEX	0	8.7	0.1	0.0	2.5	0.0	4.8	0.0	0.0	0.4							4.3
LSD .05 =	19.3	6.8	9.9	12.5	12.7	4.9	9.6	7.9	9.1	14.8	7.3	14.0	14.9	8.5	20.2	5.6	

Table 7. Rating of tree leaning from vertical (leaning 0 = no leaning; 1 = 20-45°; 2 = 45°+) of 'Starkspur Supreme Delicious' on 16 rootstocks planted in the 1984 NC-140 cooperative apple rootstock planting.

Site	B.9	MAC.1	MAC.39	P.1	P.22	SDL	CG.24	M.4	M.7 EMLA	M.26 EMLA	B.490	P.2	P.16	P.18	C6	A.313	LSD .05
AR	0.1	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.7	0.0	0.0	0.3	0.0	0.2
CA	0.3	0.0	0.5	0.3	0.7	0.0	0.4	0.1	0.0	0.2	0.0	0.9	0.3	0.0	0.1	0.1	0.4
GA	0.9	0.0	0.4	0.2	0.3	0.1	0.0	0.2	0.1	0.1							0.5
IL	1.5	0.4	0.6	0.4	1.8	0.0	1.7	0.0	0.2	0.2	0.0	1.7	1.4	0.0	1.5	0.0	0.7
IN	1.1	0.0	0.7	0.0	0.4	0.0	0.4	0.1	0.1	0.2	0.0	0.6	0.3	0.1	1.1	0.0	0.5
IA	0.0	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.6	0.4	0.0	0.4	0.0	0.3
KS	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0							NS
KY	0.4	0.0	0.0	0.0	0.3	0.0	0.3	0.1	0.1	0.1							NS
MA	0.4	0.0	0.2	0.0	1.1	0.0	0.3	0.0	0.0	0.0	0.0	1.3	1.6	0.0	0.9	0.0	0.4
MI	1.2	0.0	0.7	0.2	1.1	0.1	0.7	0.2	0.4	0.1	0.0	1.7	1.1	0.0	1.4	0.1	0.6
MN	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
OH	0.5	0.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.9	0.6	0.0	0.8	0.0	0.5
OR	1.4	0.0	0.0	0.0	0.9	0.0	0.5	0.2	0.0	0.0	0.2	1.1	1.2	0.0	1.0	0.0	0.5
ONT	0.7	0.0	0.4	0.1	1.3	0.2	0.8	0.3	0.2	0.7							0.4
PA	0.1	0.0	0.4	0.0	0.6	0.0	0.2	0.0	0.0	0.2	0.0	0.6	1.0	0.0	0.6	0.0	0.6
VA	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.4	0.0	0.1
WA	0.0	0.0	0.0	0.1	1.0	0.0	0.3	0.0	0.0	0.2	0.0	1.5	1.8	0.0	0.9	0.0	0.5
WI	0.2	0.0	0.0	0.1	0.9	0.0	0.0	0.0	0.0	0.0	0.6	0.7	0.0	0.4	0.0	0.4	
MO	1.2	0.0	1.4	1.0	1.6	0.3	0.3	0.4	0.9	0.3							0.6
UT	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.2	0.0	0.0	0.0	NS
NC	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.2	0.0	0.0	0.0	0.4	0.0	0.0	0.0	0.0	NS
TN	0.0	0.0	0.1	0.1	0.0	0.0	0.0	0.0	0.0	0.1							NS
CO	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	NS
NOS	1.6	0.0	0.7	0.4	1.8	0.0	1.6	0.4	0.4	0.0						0.5	
NJ	1.5	0.0	0.1	0.0	1.0	0.0	0.1	0.0	0.0	0.1							0.4
TX	0.0	0.1	0.0	0.0	0.0	0.1	0.1	0.0	0.0	1.0							0.5
ME	0.7	0.1	0.6	0.6	1.6	0.1	0.8	1.6	0.2	1.0	0.0	1.1	1.2	0.6	1.7	0.0	0.7
WV	0.6	0.0	0.0	0.0	0.6	0.0	0.0	0.0	0.0	0.0						0.2	
LSD .05 Rootstock	0.5	0.1	0.5	0.3	0.6	0.2	0.4	0.3	0.1	0.5	NS	0.7	0.6	0.2	0.6	NS	
Mean (LSD .05 = .12)	.51	0.2	.25	.12	.68	.02	.42	.30	.13	.09	.14	.01	.75	.62	.03	.58	

of the trees and since they were still growing, ladder length would increase in the future.

Canopy spread (Table 5) measurements indicate that trees on seedling at 5 years of age have already exceeded 60% of their allotted space of 3.5 m in CA, GA, KS, OH, OR, VA, and NC. At these sites exhibiting higher vigor, the following rootstocks exceeded or will soon exceed 60% of their allotted space: MAC. 1, CG.24, M.4, B.490, P.18 and A.313. Although it is difficult to predict ultimate tree size, the spacing of 3.5 m may be excessive for trees on P.22, P.16, P.2, B.9, and MAC.39, but appropriate for trees on C6 and M.26 EMLA.

The following sites recorded some bloom in 1985 the year following planting: CA, GA, IA, MN, OH, OR, VA, CO, NOS, and ME (data not presented). At these sites, trees on the following rootstocks had the most bloom: P.16, P.22, P.2, B.9, and C6. In 1986 bloom was present at many more sites and the data are summarized in Table 6. The following rootstocks had the greatest amount of bloom: B.9, C6, P.16, P.22, P.2, and M.26. Trees on the following rootstocks were less precocious: Seedling, MAC.1, A.313, and CG.24. At some of the sites trees on the most precocious rootstocks have fruited for 3 years and most rootstocks appear to induce more precocity and production efficiency (yield/TCSA) than apple seedling. Trees on P.16, MAC.39, B.9, and P.2 had high production efficiency.

Of the 21 sites that recorded flower cluster number in 1986 (Table 6), the following rootstocks had low flower counts at most sites: MAC.1, seedling, P.18, and A.313. On these rootstocks, CA generally had twice the number of clusters/tree compared to the other sites.

Trees on B.9, P.1, P.2, P.16, and C6 were consistently precocious at each site, but tended to exhibit high variability across sites as indicated by LSD values. As expected, the rootstocks with high bloom counts also tended to have the highest cumulative yields and efficiencies over the first 5 years (Table 2).

In 1988 all cooperators evaluated tree leaning, rating all trees for the angle of their central leader from vertical (0 = no leaning; 1 = 20-45°; 2 = 45°+). Significant leaning occurred with trees on the following rootstocks (Table 7): P.2, P.22, P.16, C6, and B.9. Trees on B.490, A.313, MAC.1, seedling, P.16 and M.7 were upright with almost no leaning. It is evident that the trees on the rootstocks with the greatest leaning in this study should have been supported at planting and many of these trees have been supported after the leaning became severe. Tree growth would likely have been greater if support had been provided from the time of planting.

The excellent tree quality and survival of trees in this planting greatly enhance the potential for additional information from this trial in future years. The NC-140 committee fully recognizes the hazard of drawing conclusions from the first 5 years of data from apple rootstock trials. However, since these rootstocks have not been widely tested in North America and are beginning to become available commercially, it was considered prudent to summarize the information realizing that future data may change some of these preliminary findings. It must be emphasized that these results were with a spur-type 'Delicious' scion and tree growth would likely be different with a more vigorous scion. Growers considering untested rootstocks should compare tree size and performance on a soil and climate as similar as possible to their site.

Literature Cited

1. Cummins, J. N. and H. S. Aldwinckle. 1982. New and forthcoming apple rootstocks. Fruit Var. J. 36(3):1-10.
2. Cummins, J. N. and H. S. Aldwinckle. 1983. "Breeding apple rootstocks" In *Plant Breeding Reviews,* (J. Janick, ed.) AVI Publishing, Westport, CT. pp. 294-394.
3. Ferree, D. C. 1982. Multi-state cooperative apple interstem planting established in 1976. Fruit Var. J. 36(1):3-6.
4. Ferree, D. C. and R. F. Carlson. 1987. "Apple Rootstocks" In *Rootstocks for Fruit Crops* (R. C. Rom and R. F. Carlson, eds.) John Wiley & Sons, NY. pp. 107-143.
5. Ferree, D. C. and R. L. Perry. 1988. Rootstock evaluation through the NC-140 project. HortScience 23(1):102-104.
6. NC-140. 1987. Growth and production of 'Starkspur Supreme Delicious' on 9 rootstocks in the NC-140 cooperative planting. Fruit Var. J. 41(1):31-39.
7. Rom, R. C. 1988. Rootstock breeding and evaluation symposium. XXII Int. Hort. Cong. 1986. HortScience 23(1):99-118.
8. Simons, R., R. Hayden, P. Domoto, F. Morrison, G. Brown, W. Lord, R. Perry, M. Warmund, D. Ferree and E. Stang. 1986. NC-140 cooperative apple interstem planting. Fruit Var. J. 40(4):108-115.

Effects of Crop Load and Harvest on Apple Ripening

WESLEY R. AUTIO AND
DUANE W. GREEN

Studies were conducted in 1989 to determine the effects of crop load and percent harvested on apple ripening. Twenty-seven 'Golden Delicious' trees were selected and partitioned into 9 blocks. The crop load on one tree in each block was adjusted to 3.4, 6.9, or 15.0 fruit cm^{-1} trunk circumference in late June. Internal ethylene was measured in 6-fruit samples taken from each tree on 25 Sept., 2, 9, and 16 Oct. Increasing crop load had a significant linear effect on delaying ripening. Approximately 11 days separated the ripening of fruit from the 3.4 fruit cm^{-1} and the 15.0 fruit cm^{-1} treatments. In a second experiment, 18 'McIntosh' trees with similar crop load were partitioned into 6 blocks. Forty percent of the crop was harvested from 1 tree and 80% from another in each block on 7 Sept. Internal ethylene was measured on 7, 14, 21, and 28 Sept. Increasing the portion of the crop initially harvested linearly delayed subsequent fruit ripening. Approximately 6 days separated the ripening of fruit from the control and the 80%-removal treatments.

HortScience 25:624, 1990

Department of Plant & Soil Sciences, University of Massachusetts, Amherst, MA 01003.

Book Review

Abrikos (Apricot), 1989, edited by Vladimir K. Smykov, published by Agropromizdat, Moscow, U.S.S.R.

Written in the Russian language, this 240-page text is an up-to-date book, particularly concerned with the investigations in the U.S.S.R. This issue summarizes the following topics: 1) An understanding of species taxonomy and their native homes; 2) Morphology of the tree and root system; 3) Morphogenesis of generative buds; 4) Winter hardiness, drought resistance, response to soil conditions; 5) Breeding; 6) Characterization of 53 standard cultivars and 21 new cultivars still under state cultivar testing; 7) Data on fruit chemical composition; 8) Establishing the apricot planting; 9) Cultural practices in the fruit-bearing orchard; 10) Control of insects and diseases.

The Soviet Union is one of the world's leaders in apricot production, whereas Central Asia, together with China, is the general area of distribution of wild species. The rich collection of the Nikitsky Botanic Garden in the Crimea is so challenging to a trained fruit breeder that a lot of new cultivars were produced. This book is concentrated on the investigations of apricot culture in the southern part of the European U.S.S.R.

by Dr. Kalyu Kask