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NC-140 1976 Cooperative Apple Interstem Planting[1]

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ABSTRACT

Interstems of M.9 on MM.111, Antonovka and Ottawa 11 rootstocks with 2 scion cultivars were planted in 10 locations in 1976 and handled according to the guidelines established by NC-140. Tree loss on MM.111 was 9% or less over 9 years, but losses exceeded 16% on the other rootstocks. Trees of 'Empire' were 25% larger and 36% more productive than trees of 'Sturdeespur,' as well as more efficient on each rootstock. 'Empire' was more efficient than 'Sturdeespur' and trees on Antonovka were most efficient followed by Ottawa 11 and MM.111. Scions and interstems on Ottawa 11 suffered the greatest winter injury, MM.111 the least with Antonovka intermediate.

Evaluations of potential apple rootstocks and interstem systems have been conducted independently by many states in the past. The lack of common planting materials, spacing and handling procedures made comparisons of the results of previous studies difficult. In 1974, a group of researchers agreed as part of NC-140 to develop an interstem trial using common planting materials and management guidelines developed by the committee.

Interstems were chosen for this first common trial because of the desire for a small freestanding tree and the inability of available rootstocks to fill this need. Tree size decreases as the length of interstem is increased (1,15) and an interstem length of 6-8 inches would produce a tree that could be handled mostly from the ground. In comparison of the performance of interstem trees with conventional rootstocks, yields of M.9 and M.27 interstems on MM.106 and MM.111 were similar to trees on M.26 or M.9 (13). Interstem trees have an open spreading canopy and high physiological efficiency when judged either by fruit per unit of leaf area or fruit per unit of trunk cross section (5). The rootstock portion of interstem trees can influence anchorage, tree size control, as well as soil and climatic adaptability. Antonovka seedling and Ottawa 11 were selected as rootstocks that should provide tree stability and be cold hardy, but little was known of their influence on soil adaptability, precocity or productivity. Preliminary data from this trial indicated that interstem trees on MM.111 were 15-20% smaller than those on Antonovka seedling or Ottawa 11 for both cultivars (6). Ottawa 11 tended to produce fewer rootsuckers than Antonovka or MM.111. Differences among the sites and cultivars in growth pattern and production of rootsuckers were also observed, but final assessment was withheld until the termination report published here.

Materials and Methods

Trees for this study were propagated by double-grafting scions of 'Sturdeespur Delicious' and 'Empire' on a 15 cm (6") piece of M.9 and subsequently grafted to rootstocks of MM.111, Ottawa 11, and seedlings of Antonovka. The trees were grown in the nursery for one year and sent to the 10 cooperative states in the spring of 1976. The trees were planted according to a separate randomized plan for

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each state at a spacing of 3.66 m x 5.49 m (12′ x 18′) with the lower union of the interstem 5 cm (2″) above the soil line. The trees were trained to a central leader and pruned by a uniform set of guidelines established by the NC-140 committee. The treatments were arranged in a randomized complete block design with 7 individual tree replicates. Due to a shortage of trees, IL did not receive 'Sturdeespur'/MM.111 and 'Empire'/Ottawa 11.

The following data was collected annually for each tree: interstem circumference, scion circumference, number of rootsuckers, tree height, tree spread, yield/tree, and average fruit weight. Weather data was also collected on a monthly basis for each site. A soil sample was taken prior to planting and again in August 1980. A composite sample of mid-terminal leaves from each treatment was taken in August 1980. Upon termination of the trial in November 1984, crosssections of the scion trunk at 5 cm (2 in.) above the graft union, and the interstem at the midpoint were examined for winter injury. Injury was interpreted as the percentage of wood that had become discolored, commonly referred to as blackheart.

Results

Tree loss was minimal on MM.111 but significant and unacceptable on both Antonovka and Ottawa 11 with the greatest loss on Antonovka (Table 1). Tree mortality of 'Sturdeespur' and 'Empire' over all the plantings was 32% and 22%, respectively. IA, KS, and OH had smaller losses than the other locations where losses were generally unacceptable.

In general, 1982 was the coldest year during this trial and 1977 the year after planting was the next coldest winter (Table 2). The lowest temperature experienced was -28°F in 1982 in MA, followed by a -26°F in 1979 in IA. All states except MI and MO experienced -20°F or lower during 1 or more years of the study. The KS and MO sites experienced the highest temperatures of 109°F in 1980. Although the brief summary presented in Table 2 does not provide detailed weather data needed to explain tree growth, it does indicate the range of extremes over the years in which the trees were grown.

Generally, trees of both cultivars on MM.111 were smaller than either Antonovka or Ottawa 11, but there were notable exceptions in both height and spread among states (Table 3). However, most of the cultivar interstem

Table 1. Tree mortality in the regional interstem planting established in 1976 by the NC-140 committee.

	Number of Trees Lost*						Total
	Sturdeespur/M.9			Empire/M.9			%
State	MM.111	Ant.	0-11	MM.111	Ant.	0-11	Lost
IL	—	3	2	0	0	—	18
IN**	0	4	0	0	4	1	21
IA	0	0	0	0	0	2	5
KS	0	2	0	0	2	0	9
MA	1	2	3	2	1	0	21
MI	3	4	1	0	2	2	29
MO	0	0	1	0	3	3	17
OH	1	1	1	0	1	1	9
WI	0	0	7	0	0	1	19
Total % Lost	9	25	24	3	21	16	—

*All states received 7 trees of each combination.
**Loss up through 1982.

Table 2. Air temperature extremes (°F) at the sites of the regional interstem planting established in 1976 by the NC-140 committee.

	1976		1977		1978		1979		1980	
State	Max	Min	Max	Min	Max	Min	Max	Min	Max	Min
IL	NA	NA	96	-20	93	- 6	85	6	NA	NA
IA	95	-17	101	-22	101	-22	94	-26	97	-14
KS	NA	NA	104	- 9	104	-11	98	-15	104	- 8
MA	96	-11	95	- 9	47	- 6	96	-14	96	0
MI	NA	NA	NA	NA	94	-11	94	-13	NA	NA
MO	NA	NA	NA	NA	98	-18	NA	NA	109	-13
OH	89	- 8	91	-20	93	- 9	87	-12	95	- 3
WI	95	-17	95	-23	91	-10	89	-23	90	- 9
KY	97	- 4	96	-14	100	- 2	95	- 5	102	- 1
IN	NA	NA	98	-19	92	-13	NA	NA	100	- 4

	1981		1982		1983		1984	
	Max	Min	Max	Min	Max	Min	Max	Min
IL	92	- 9	99	-18	103	- 1	104	- 6
IA	92	- 9	99	-18	103	- 1	104	-15
KS	94	-20	93	-25	100	-21	98	-23
MA	100	-10	93	-23	99	- 6	95	-20
MI	91	-15	102	-15	107	- 3	103	-18
MO	97	-11	96	-16	100	-14	98	-14
OH	89	-10	95	-11	94	- 5	95	-17
WI	82	-13	91	-15	93	- 1	90	-19
KY	95	- 3						
IN	93	-10						

combinations in this study could be managed from the ground and were free-standing. KS tended to have the largest 'Sturdeespur' trees on all rootstocks and larger trees on MM.111, but no clear pattern was evident for Antonovka and Ottawa 11. Trees from WI tended to be shorter than trees from other states, but spread did not differ greatly from other states. These overall measurements of canopy size generally corresponded closely to the measurements of trunk cross-sectional area (Table 4).

Yield/tree at 9 years of age in 1984 was highest on Ottawa 11 for both cultivars, but when the smaller tree size of MM.111 was taken into account, there was little difference in yield efficiency of trees on MM.111 or Ottawa 11 (Table 4). Cumulative yield over the years of production (1979-1984) followed a similar pattern with trees of Ottawa 11 having the highest yield, trees on MM.111 the lowest and trees on Antonovka in between (Table 5).

Cumulative yield efficiency as evaluated by fruit production per unit of trunk area indicated that the trees on Antonovka were more efficient than trees on either MM.111 or Ottawa 11 (Table 5). MA tended to have the most efficient trees and IA the least efficient of the test sites.

Some degree of wood injury was found in the scion and interstem trunk cross sections at 6 of the 7 sites reporting (Table 6). No injury to either the scion or interstem wood was found in the WI planting (not included in the overall analysis). The IA planting suffered the greatest injury, followed by MO and KS, while MA and MI had the least injury. Generally, 'Sturdeespur' trees suffered less scion injury than 'Empire', but there were no differences among cultivars in interstem injury. Analysis by individual states showed that significant cultivar effects

Table 3. Tree height and spread in 1984 of M.9 interstem apple trees in a regional planting established in 1976.

	Tree Height (cm)						Tree Spread 1984 (cm)					
	Sturdeespur/M.9			Empire/M.9			Sturdeespur/M.9			Empire/M.9		
State	MM.111	Ant.	O-11	MM.111	Ant.	O-11	MM.111	Ant.	O-11	MM.111	Ant.	O-11
IL	—	252	304	227	248	—	—	240	256	295	328	—
IA	185	240	242	201	233	250	147	193	205	216	272	305
KS	300	270	315	280	260	264	372	317	405	303	248	321
MA	213	277	263	217	272	264	134	280	284	344	389	379
MI	192	233	236	222	244	278	180	226	188	242	310	336
MO	234	259	204	219	189	249	193	222	131	236	220	277
OH	246	251	261	232	248	265	211	250	280	338	411	397
WI	178	210		170	150	157	202	283		329	307	317
LSD .05			46						53			
Avg.	221	249	260	221	230	246	205	250	249	287	310	333

for both scion and interstem wood were evident only in states with the least injury. Based on both scion and interstem cross-sections trees on Ottawa 11 exhibited the greatest wood injury, trees on MM.111 the least with Antonovka trees intermediate. States followed the same trend with Antonovka being either different or not different from MM.111 or Ottawa 11 or both. The only significant interactions showed that 'Sturdeespur'/MM.111 had less scion and interstem injury than 'Empire'/MM.111 in the IA planting, while in the MI planting, no significant differences between rootstocks was found for interstem injury when 'Sturdeespur' was the scion (data not shown).

Discussion

At the end of the study, 8 out of the original 10 plantings remained. It was previously reported that the KY planting was removed because of poor tree growth following severe frost heaving (6). The IN planting was removed in 1983 due to poor tree growth that was attributed to wet soil conditions and a dogwood bore *(Synanthedon scitula)* infestation of the M.9 interstem. Tree loss after 9 years had a pattern similar to that reported in 1981 (6), but at that time only 'Sturdeespur' on Ottawa 11 had an unacceptable tree loss. Much of that early loss was attributed to poor tree quality and lack of vigor associated with double grafting. Norton (14) also emphasized the importance of good quality nurserystock for interstem trees to make good growth. Since 1981, the greatest loss occurred on Antonovka followed by Ottawa 11. The significant increase in tree loss on Antonovka and Ottawa 11 may have been due to fireblight *(Erwinia amylovora)* infections which were observed on rootsuckers of Antonovka at several sites. Previous work indicated slightly less tree loss of interstem trees to fireblight when MM.111 was the rootstock compared to apple seedling, M.7 or MM.106 (6). No tree loss was directly attributed to soil adaptability or soil borne disease. Breakage at the graft unions or of the M.9 interstem was minimal. Vandalism accounted for the major loss of trees in the MI planting. Loss attributed to winter injury was minimal and confined to Ottawa 11 in the IA planting. A comparison of tree mortality on the following rootstocks over a 13-year period indicated that only MM.111 and Apple Seedling had acceptable survivability: M.7, M.9, M.26 and MM.106 (8). Results of the present study support the wide adaptability of MM.111 and the

Table 4. Tree size and yield in 1984 of M.9 interstem apple trees in a regional planting established in 1976.

	TCA 1984 (mm^2)					
	Sturdeespur/M.9			Empire/M.9/M.9		
State	MM.111	Ant.	O-11	MM.111	Ant.	O-11
IL		3235		3559	4069	
IA	2655	3897	4657	3015	5418	6525
KS	7481	6445	9521	5593	6577	6501
MA	1402	3859	2973	2725	3991	4740
MI	1263	3972	3421	2816	4834	7327
MO	1625	2256	4307	2788	2052	5091
OH	3337	4252	4140	4462	7582	8525
WI	1861	3298	——	3041	3521	3510
			LSD .05 = 2425			
Avg.	2681	3902	3960	3520	4631	5847
			Yield/1984 (Kg)			
IL		1.7	13.8	33.8	44.8	
IA	—	—	—	3.6	5.8	13.4
KS	10.8	7.5	9.1	13.5	5.8	9.1
MA	7.1	12.4	19.0	18.4	44.0	45.1
MI	5.2	18.0	14.0	25.4	42.6	36.2
MO	—	1.0	2.7	17.8	4.0	20.5
OH	7.7	15.7	36.4	19.3	30.9	58.3
WI	19.1	38.1	—	28.5	23.0	30.1
			LSD .05 = 21.7			
Avg.	8.7	14.2	20.4	22.9	29.7	40.7
			Yield/TCA Area 84 (Kg/cm^2)			
IL		.06		.83	1.09	
IA	—	—	—	.12	.10	.23
KS	.15	.13	.05	.59	.05	.11
MA	.38	.35	.63	.67	1.12	.95
MI	.34	.47	.61	.93	.93	.67
MO	—	.04	.06	.60	.30	.41
OH	.23	.37	.87	.43	.41	.68
WI	1.00	1.16	—	.89	.61	.94
			LSD .05 = .60			
Avg.	.42	.37	.63	.63	.57	.57

ability of trees to survive on this rootstock under a wide range of conditions.

Trees often recover from blackheart, but it can affect tree performance. Cross-section analysis of the trunks showed that the rootstock affected the hardiness of the trees in 6 of the 7 states reporting with Ottawa 11 imparting the least cold resistance, followed by Antonovka. Additionally, IA reported interstem bark injury after 2 winters that followed the same trend,

Table 5. Cumulative (1976-1984) yield and yield efficiency of M.9 interstem apple trees in an 8-state regional planting.

Cultivar Rootstock	Cumulative Yield (Kg/T)								
	IL	IA	KS	MA	MI	MO	OH	WI	Avg.
Sturdeespur									
MM.111	—	29.3	86.9	30.1	41.4	26.6	50.3	40.5	41.7
Antonovka	59.4	50.5	90.6	86.4	55.0	33.3	56.3	78.6	64.8
Ottawa 11	65.3	66.5	135.5	73.6	41.3	61.3	76.6	—	78.9
Empire									
MM.111	52.1	37.9	82.2	67.6	48.3	61.1	76.9	66.9	64.4
Antonoka	85.7	76.2	85.4	129.3	90.0	32.8	196.1	96.5	103.3
Ottawa 11	—	100.1	108.4	144.3	64.4	70.1	211.6	88.8	121.8
LSD .05 =	37.7	19.8	ns	38.2	18.7	24.4	28.3	33.4	15.4
Overall LSD .05 =					4.31				
	Cumulative Yield/TCA (Kg/cm²)								
Sturdeespur									
MM.111	—	1.07	1.19	1.53	3.01	1.58	1.51	2.06	1.59
Antonavka	1.76	1.23	1.32	2.33	1.41	1.41	1.36	2.39	1.74
Ottawa 11	.04	1.44	1.47	2.33	1.49	1.38	1.85	—	1.63
Empire									
MM.111	1.48	1.26	1.75	2.72	1.76	2.10	1.79	2.18	1.95
Antonovka	2.06	1.42	1.66	3.46	1.88	1.89	2.58	2.70	2.31
Ottawa 11	—	1.59	1.91	3.10	1.12	1.28	2.48	2.47	2.08
LSD .05 =	.90	.26	NS	1.15	1.17	NS	.52	NS	.83
Overall LSD .05 =					.87				

but found little wood injury in the rootstock portion of the trees with no differences between rootstocks (4). Based upon the bark injury and temperature records, it was concluded that the IA injury occurred in late winter. Ottawa 11 (3) and Antonovka (10) have been reported to be susceptible to cold injury following mid- to late-winter thaws, while controlled freezing of MM.111 shoots showed it to deharden during thaws, it can also reharden (9). Although differences reported by states here were probably indicative of the year the injury occurred, states reporting the greatest injury were those more prone to fluctuating winter temperatures and not necessarily those that experienced the coldest temperatures (Table 2). Particularly the WI planting which was located on Door Peninsula, experienced little fluctuation of winter temperature and had no injury.

Burrknots on the M.9 interstem were observed to some degree in all of the plantings. Burrknots can serve as entry sites for insect larva and fireblight, and caused trunk fluting which could interfere with vascular transport and weaken the tree (16). It has also been reported that trees with burrknots are more susceptible to cold injury, with root germs on rootstock shoots being killed at 5°F (-15°C) or above (12). Exposing a smaller portion of the rootstock (or interstem) has been suggested as a practical method of control (16). In this study, both graft unions were above the soil line and this may have contributed to the loss and poor performance of trees at several sites.

Table 6. Percentage of discolored wood (blackheart) in scion and interstem cross-sections of M.9 interstem apple trees in an 8-state regional planting.

Treatment	IL	IA	KS	MA	MI	MO	OH	WI*	Avg.
	Scion Cross-Section								
State	—	58	29	18	20	36	24	—	
LSD 0.05					6.1				
Sturdeespur	—	56	27	11	13	34	20	0	29
Empire	—	59	30	23	25	39	29	0	34
LSD 0.05	—	9.2	9.7	9.1	3.0	10.9	22.8	—	4.3
ST × CV LSD					9.5				
MM.111	—	40	16	15	15	18	11	0	19
Antonovka	—	63	29	13	21	43	27	0	35
Ottawa 11	—	73	41	25	24	56	36	0	42
LSD 0.05	—	8.8	5.6	7.2	7.6	19.3	16.4	—	4.7
ST × RS LSD					11.5				
	Interstem Cross-Section								
State	—	58	39	13	7	43	—	—	
LSD 0.05					7.5				
Sturdeespur	—	57	37	7	5	45	—	0	34
Empire	—	60	41	17	8	41	—	0	34
LSD 0.05	—	13.9	12.4	5.0	2.3	9.1		—	3.8
ST × CV LSD					9.2				
MM.111	—	24	29	8	2	15	—	0	16
Antonovka	—	72	40	8	7	48	—	0	38
Ottawa 11	—	83	49	22	11	77	—	0	48
LSD 0.05	—	17.8	9.2	5.8	4.9	18.2	—	—	5.8
ST × RS LSD					12.2				

*Not included in the overall analysis.

An observation in the IA planting suggested that exposure of the rootstock above the ground may have influenced the cold resistance imparted by the rootstock (4). Rootsuckering was high in this study (6), and it has been reported that burying a portion of the interstem reduced suckering (2).

Norton (14) concluded from results of extensive planting in NY that if MM.106 was the rootstock for interstem trees, a portion of the M.9 interstem should be buried at planting. However, if MM.111 or other more vigorous rootstocks were used, the entire M.9 interstem should be exposed above the soil line to reduce tree growth and increase early bearing. A VT study found that planting depth had no effect on the size of interstem trees after 6 years (2). Until this matter is more fully resolved, the tree size results reported here must be interpreted with some reservation. However, because of the problems encountered in this study, it is recommended that interstem trees be planted with minimum exposure of the interstem above the ground. The effect of deeper planting on scion hardiness remains to be tested, and is further complicated by the potential of interstem rooting.

Most trees in this study did not fill their allotted space of 12 feet (365 cm).

The only exceptions being 'Empire' on Antonovka and Ottawa 11 in MA and OH (Table 3). The following spacings could have been used for M.9 interstems: 'Sturdeespur'/MM.111, 6′ x 12′; 'Sturdeespur' on either Ottawa 11 or Antonovka, 8′ x 14′; 'Empire'/MM.111, 9′ x 15′; and 'Empire'/Antonovka, 10′ x 16′; 'Empire'/Ottawa 11, 11′ x 17′. Thus, orchard efficiency of all these combinations could be improved by closer planting than the 12′ x 18′ used in this study. Although some leaning occurred, particularly when 'Sturdeespur' was the scion, trees of all combinations were generally free-standing and all the management chores could be conducted from the ground.

If yields/acre are calculated based on the potential spacings above, interstems of 'Sturdeespur' on MM.111 become as efficient as on Antonovka, but still 18% less efficient/acre compared to 'Sturdeespur' on Ottawa 11. Interstems of 'Empire'/MM.111 even with yield/acre calculated on actual tree size were still 26% less efficient/acre than interstems on Antonovka or Ottawa 11 which were equivalent. Thus, based on yield potential and efficiency, Antonovka and Ottawa 11 would be preferred as rootstocks for interstem trees. However, the long-term nature of apple orchards and the demonstrated significant tree loss that occurred after the trees were 5-years-old (Table 1) would preclude them from consideration. When all factors are considered, MM.111 would be the preferred of the rootstocks in this study to support interstem trees. However, it is obvious that greater productivity can be achieved and an improved rootstock for interstems should be sought.

Literature Cited

1. Carlson, R. F. and S. D. Oh. 1975. Influence of interstem lengths of M.8 clone Malus sylvestris Mill. on growth, precocity, yield and spacing of apple cultivars. J. Amer. Soc. Hort. Sci. 100:450-452.
2. Constante, J. F., W. J. Lord, S. Lacasse and D. Howard. 1982. Responses of interstem apple trees to planting depth. Compact Fruit Tree. 15:25-29.
3. Cummins, J. N. and H. S. Aldwinckle. 1982. New and forthcoming apple rootstocks. Fruit Var. J. 36:66-73.
4. Domoto, P. A. 1986. Winter injury effects on M.9 interstem apple trees. Compact Fruit Tree (in press).
5. Ferree, D. C. 1980. Canopy development and yield efficiency of 'Golden Delicious' apple trees in four orchard management systems. J. Amer. Soc. Hort. Sci. 105:376-380.
6. Ferree, D. C. 1982. Multi-state cooperative apple interstem planting established in 1976. Fruit var. J. 36(1):3-6.
7. Ferree, D. C. 1982. Tree performance and yield efficiency of several apple cultivars on M.9 and M.9 interstems. Fruit Crops 1982: A Sum. of Res., OARDC Res. Circ. 272:7-4.
8. Ferree, D. C. and R. G. Hill, Jr. 1982. Influence of six rootstocks and herbicides on growth, cropping and fruit quality of Blaxtayman apple trees. Fruit Crops 1982: A Sum. of Res. OARDC Res. Circ. 272:3-6.
9. Forsline, P. L. 1983. Winter hardiness of common New York apple varieties and rootstocks as determined by artificial freezing. Proc. NY St. Hort. Soc. 128:20-42.
10. Gruca, Z. 1978. Factors affecting changes of frost resistance of some clonal rootstocks. Acta. Hort. 81:103-106.
11. Hall, F. R., M. A. Ellis, and D. C. Ferree. 1982. Influence of fireblight and ambrosia beetle on several apple cultivars on M.9 and M.9 interstems. Fruit Crops 1982: A Sum. of Res., OARDC Res. Circ. 272:20-24.
12. Holubowicz, T., J. N. Cummins and P. L. Forsline. 1982. Responses of Malus clones to programmed low-temperature stresses in late winter. J. Amer. Soc. Hort. Sci. 107: 492-496.
13. Lord, W. J., D. W. Greene, R. A. Damon, Jr. and J. H. Baker. 1985. Effects of stempiece and rootstock combinations on growth, leaf mineral concentrations, yield and fruit quality of 'Empire' apple trees. J. Amer. Soc. Hort. Sci. 110:422-425.
14. Norton, R. L. 1981. Interactions of apple rootstocks and varieties. Hort. News 61(2): 4-19.
15. Roberts, A. N. and L. T. Blaney. 1967. Qualitative, quantitative and positional aspects of interstock influence on growth and flowering of the apple. Proc. Amer. Soc. Hort. Sci. 91:39-50.
16. Rom, R. C. 1970. Burrknot observations on clonal apple rootstocks in Arkansas. Fruit var. Hort. Dig. 24:66-68.