

EFFECT OF STOCK-SCION COMBINATIONS ON THE PERFORMANCE OF APPLES¹

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This five year study was originally designed to observe the performance of four scion, five interstem, and ten rootstock varieties, in all possible combinations (Table 1). However, of all the factors that ultimately determine the usefulness of any graft combination, only survival, compatibility, and anchorage, will be covered here.

The plants were propagated at a commercial nursery in 1955 and 1956. Six-inch rootstock pieces were grafted to three-inch nurse root pieces of Western apple seedlings, using the whip and tongue technique. The grafts were callused and field grown for one season. In 1956, "two eye" stem pieces of the scion varieties were bench grafted to five-inch sections of the interstem varieties. The grafts were callused until bud break in the spring and then grafted, in the field, onto the rootstocks.

Survival

All failures in this study occurred during the first four years of growth. The specific combinations that failed completely were: Yellow Delicious/Clark Dwarf/Columbia; Yellow

Table 1 Selected Scion, Interstem, and Rootstock Varieties

Scions	Interstems	Rootstocks
Jonathan	Ottawa-524 ¹	Columbia
Red Delicious ²	Clark Dwarf ³	Bedford
Yellow Delicious ⁴	Malling IX ⁵	Hopa
Winesap	Robin	Dolgo
	Malling VII ⁶	Anoka
1 Hereafter 0-524		Beacon
2 " in tables	Red Del.	
3 " " "	Clark	Hawk. Grng.
4 " " "	Yel. Del.	
5 " " "	M IX	McIntosh
6 " " "	M VII	Yel. Del.
		Robusta #5

Delicious/M IX/Anoka; Winesap/Clark Dwarf/Hawkeye Greening; Winesap/Robin/Hopa; Red Delicious/MVII/Hawkeye Greening and Winesap/Robin/Hopa.

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Rootstocks:

The Dolgo and Bedford rootstocks resulted in the highest percent survival, with 90 and 92 percent respectively. Survival of the other rootstocks ranged from 71 to 82 per cent for all except Hawkeye Greening which was only 58 per cent.

Columbia performed well with the M VII and to a lesser degree with the Red Delicious scion variety. Survival was excellent with Clark Dwarf, Robin, and M VII/Bedford combinations and poor with the M IX/Bedford combination. Bedford also performed well with all but the Jonathan scion variety. Although, survival was high in the Jonathan/Clark Dwarf/Bedford combination. Survival was high with Jonathan/M IX/Hopa. Survival was poor with all other Hopa combinations. Dolgo with the Robin and M VII interstems and all scion varieties resulted in good survival percentages. This was especially evident with the Red Delicious and Yellow Delicious varieties. Anoka gave excellent performance only with the Jonathan scion variety and borderline performance with the M VII interstem. Beacon's performance was poor with all the interstems. However, the Winesap/Beacon combinations resulted in a high survival per cent regardless of the interstem used. McIntosh performed poorly with all interstems and scion varieties except the Red Delicious scion variety. Yellow Delicious, as a rootstock, resulted in satisfactory combinations only with the Yellow Delicious scion variety. All M VII/Robusta #5 combinations survived. Jonathan was the only scion variety that combined well with the Robusta #5 rootstock. The Robin/Robusta #5 combinations resulted in borderline performance when considering survival.



Figure 1. Rabbit damage on a Clark Dwarf interstem. Yellow Delicious/Clark Dwarf/Yellow Delicious tree damaged during the winter of 1959-1960. Rabbits showed a definite preference for the bark of the dwarfing interstems.

Interstems:

Before assessing the survival of the interstems, it should be realized that rabbits showed a definite preference for the dwarfing interstems. Also, the O-524 interstem has been eliminated from further consideration because of the prevalence of stem pitting found in the experimental material.

When interstem performance was considered, Clark Dwarf and M IX combinations resulted in the lowest survival rates. Clark Dwarf did give excellent survival with the Bedford rootstock and borderline performance with both Hopa and Dolgo rootstocks. Clark Dwarf, in combination with Jonathan, Red Delicious or Yellow Delicious scions resulted in approximately 75 percent survival, while only 53 per cent of the Winesap scion trees survived. Malling IX performed very well in combination with the Hopa rootstock. Borderline survival resulted from the Columbia and M IX/Dolgo combinations. This interstem resulted in 87 per cent survival with the Red Delicious scion and gave approximately 75 per cent survival with Jonathan and Winesap. Only 56 per cent of the Yellow Delicious scion combinations trees survived. M VII gave 100 percent survival in com-

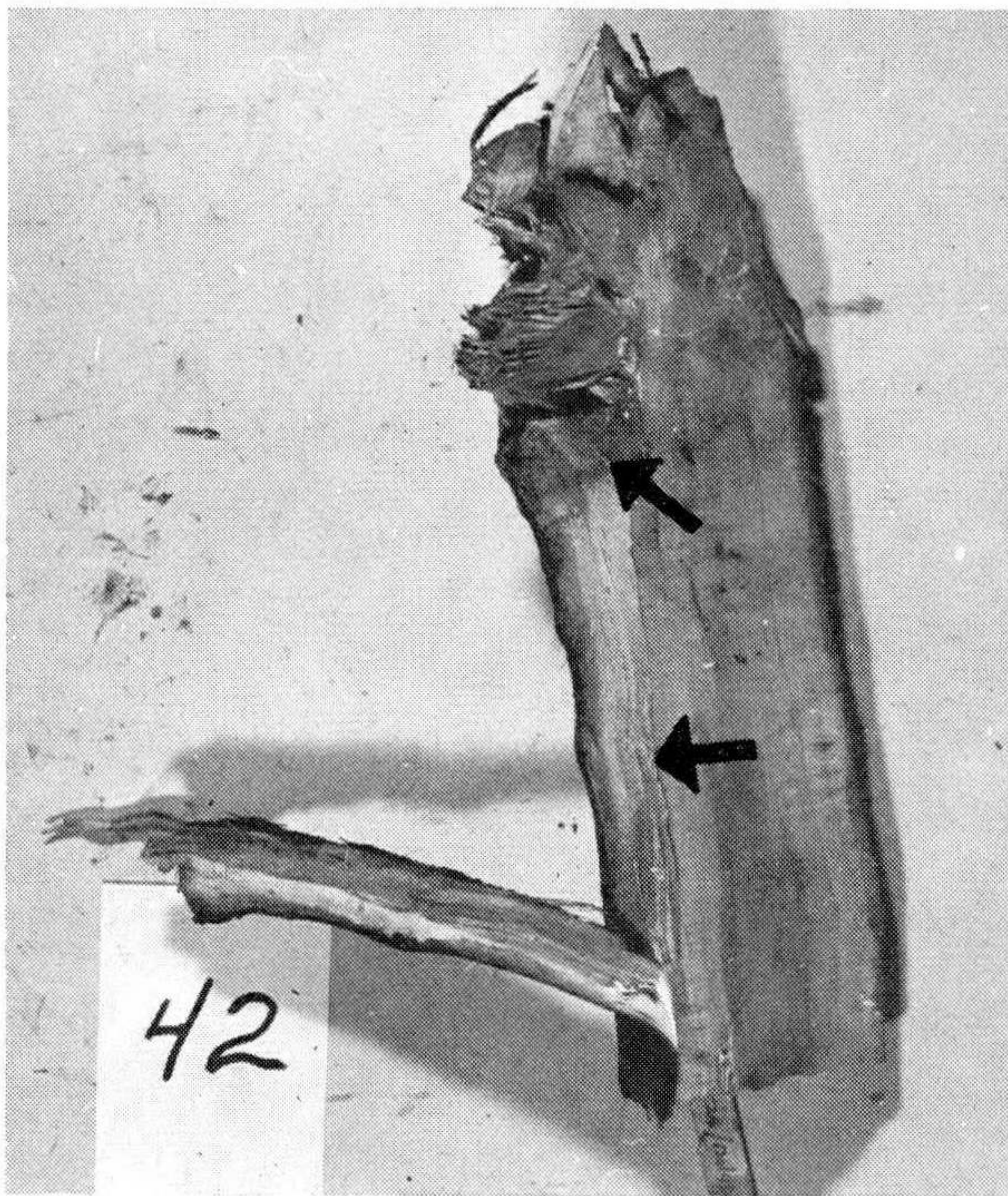


Figure 2. Strong graft unions between scion, interstem and rootstock. This Red Delicious/O-524/Dolgo tree exhibited strong smooth graft unions. The arrows indicate the location of the graft unions.



Figure 3. Protuse suckering of a Yellow Delicious/Clark Dwarf/Hopa combination. Note the broken interstem-rootstock union.

bination with both Bedford and Robusta #5 rootstocks. Approximately 84 per cent survival was realized with all scion varieties in combination with M VII.

The per cent failure of rootstocks, interstems and scions is presented in Table 2.

Compatibility

All Winesap /Robin/Hopa trees snapped at the scion/interstem union. Indications of incompatibility were also observed in the M IX/Beacon combination, in which six of the twelve plants failed during the first year in the field.

Vertical splitting of the interstem was observed in the Red Delicious/M IX/Anoka, Yellow Delicious/0-524/Hawkeye Greening, Red Delicious/Clark Dwarf/Anoka, Jonathan/0-524/Beacon, and Red Delicious/0-524/Anoka. No detrimental effects from the splitting were detected, since the wounds healed during the growing season.

Where possible, at least one tree in a combination was pulled with a TD-6 International Track-type tractor. Since this tractor could develop in excess of 20,000 pounds pull, breakage at a graft union does not necessarily imply the existence of incompatibility. However, breakage of this nature does signify a weakness in comparison to the other parts of the plant. Many combinations were pulled intact, although overgrowth of the interstems, another accepted symptom of incompatibility, was evident in some of the combinations. The combinations which displayed abnormalities at the time of uprooting are presented in Table 3.

Most trees that were broken in the pulling appeared sturdy and healthy. Combinations with the Jonathan scion variety contained more trees which were broken at the time of pulling

than any of the other scions. Jonathan trees also had the highest rate of survival. The possibility exists that the more brittle nature of these graft unions will ultimately result in the loss of many apparently healthy trees.

Anchorage

Poor anchorage is accepted as a common failing of most dwarfing rootstocks in use today. Size and type of root system, the angle the roots take from the crown, and the mechanical strength of the roots are a few of the factors that enter into the anchorage problem. The interstem system allows the use of a good root type without the drawbacks of the dwarfing rootstock.

Anchorage and root development were ascertained visually each year as well as at the time the trees were uprooted mechanically. Any tree leaning off center was assumed to have poor anchorage, unless the cause could be ascribed to mechanical or rodent injury. Fifty-three of the 200 combinations displayed a tendency to lean (Table 4).

The Winesap scion produced the highest number of leaning trees, followed by Red Delicious and Yellow Delicious. All Jonathan scion trees were well anchored.

The dwarfing interstem combinations were expected to show the greatest tendency towards poor anchorage. However, the Yellow Delicious/MIX and Jonathan/MIX trees were particularly well anchored. Jonathan/M VII/Columbia gave sparse root development, while the Jonathan/0-524/Columbia possessed a strong but restricted root system. Brittle roots that snapped easily when pulled and which grew at a wide angle to the axis of the crown were found on Jonathan/M VII/Bedford and Jonathan/Robin/Robusta #5. These represent only three of the fifty Jonathan combinations, and, of these, two had M VII as the interstem.



Figure 4. Overgrowth of the scion and poor anchorage. Winesap/M VII/Beacon tree exhibiting overgrowth of the scion and poor anchorage.



Figure 5. Red Delicious/Robin/Robusta #5. An extensive system of large, fibrous roots was produced by this combination.

In considering the interstem, M VII was associated with the greatest number of poorly anchored trees. It should also be noted that fifty per cent of them had Winesap as the scion variety. Robin followed, with twelve faulty combinations which were divided quite evenly between Winesap and Red Delicious. Clark Dwarf was involved in ten poorly anchored combinations; six of which had Winesap as the scion. Malling IX followed, with nine poorly anchored combinations, seven with Winesap scions. It appeared that Winesap generally reacted with the interstems used here to produce poorly anchored trees.

A 10,000 pound draw meter was used to measure the pounds of pull required to uproot trees with the TD-6 tractor. The draw for trees requiring more than a 10,000 pound pull for uprooting was estimated by a very experienced tractor operator. The average amounts of pull required to uproot the trees is recorded in Table 5.

There were almost as many variations found in root development as there were graft combinations. Based on this method of evaluation, combinations with the Winesap scion variety were somewhat easier to uproot than the other scion varieties. The two dwarfing interstocks, Clark Dwarf and Malling IX, gave the poorest anchorage of the interstems. Malling VII was intermediate in anchorage between the dwarfing stocks and the more vigorous 0-524 and Robin interstems. The differences in uprooting the rootstocks were relatively small. Columbia, Bedford, Anoka, Beacon, and Robusta #5 were easiest to uproot. Hopa, Hawkeye Greening, McIntosh and Yellow Delicious were intermediate. Dolgo required the greatest number of pounds pull for uprooting.

The findings of this study demonstrate that there are special combinations that perform most satisfactorily under a given

Table 2 Failure of rootstocks, interstems and scions in per cent

Component	Total
<i>Rootstocks</i>	
Columbia	23
Bedford	8
Hopa	18
Dolgo	10
Anoka	20
Beacon	29
Hawkeye Greening	42
McIntosh	28
Yellow Delicious	20
Robusta #5	26
<i>Interstems</i>	
0-524	15
Clark	31
M IX	27
Robin	23
M VII	16
<i>Scions</i>	
Jonathan	18
Red Delicious	18
Yellow Delicious	24
Winesap	30

Table 3. Combinations showing growth abnormalities at the time of pulling

Combination	Union where breakage occurred
Jonathan/Clark/Hopa	Interstem/rootstock
Jonathan/Robin/Robusta #5	Interstem/rootstock
Red Del./Clark/Hopa	Interstem/rootstock
Red Del./M VII/Columbia	Interstem/rootstock
Winesap/M VII/Bedford	Interstem/rootstock
Jonathan/Robin/Dolgo	Interstem/rootstock
Jonathan/M VII/Beacon	Scion/interstem
Jonathan/M VII/McIntosh	Scion/interstem
Jonathan/M VII/Robusta #5	Scion/interstem
Jonathan/0-524/Beacon	Interstem/rootstock
Jonathan/0-524/Yel. Del.	Interstem/rootstock
Jonathan/Robin/Robusta #5	Interstem/rootstock
Jonathan/Clark/Hopa	Interstem/rootstock
Jonathan/Clark/McIntosh	Interstem/rootstock
Jonathan/Clark/Anoka	Interstem/rootstock
Jonathan/M IX/Bedford	Interstem/rootstock
Red Del./Clark/Dolgo	Interstem/rootstock
Red Del./M VII/Columbia	Interstem/rootstock

Red Del./0-524/Anoka	Interstem/rootstock
Yel. Del./M VII/Bedford	Scion/interstem
Yel. Del./Clark/Hopa	Interstem/rootstock
Yel. Del./0-524/Hopa	Interstem/rootstock
Winesap/M VII/Bedford	Interstem/rootstock
Winesap/M IX/Hopa	Interstem/rootstock
Winesap/Clark/Beacon	Scion/interstem
Winesap/M IX/Beacon	Interstem/rootstock

Table 4. Combination observed to possess poor anchorage¹

Rootstock	Interstem																			
	0-524 Scion				Clark Scion				M IX Scion				Robin Scion				M VII Scion			
	J	R	Y	W	J	R	Y	W	J	R	Y	W	J	R	Y	W	J	R	Y	W
Columbia	X		X					X	X											X
Bedford				X				X					X	X	X					X X
Hopa							X													X X
Dolgo								X			X				X		X			X X
Anoka				X	X		X		X	X			X	X			X	X		
Beacon	X							X			X						X			X
Hawk. Grng.											X				X					X
McIntosh			X			X					X		X	X						X
Yel. Del.								X			X		X				X			X
Robusta #5						X					X		X	X						X

¹Many of these combinations showed the tendency to lean early in development. However, a large percentage later developed strong root systems and became well anchored.

Table 5. Average minimum pull required to uproot trees, based on component parts

Scions	pull Pounds	Rootstocks	Pounds pull	Inter-stems	Pounds pull
Jonathan	12,961	Columbia	11,000	0-524	12,250
Red Del.	12,158	Bedford	11,167	Clark	9,750
Yel. Del.	12,467	Hopa	12,444	M IX	9,846
Winesap	10,333	Dolgo	13,333	Robin	13,037
		Anoka	11,400	M VII	11,950
		Beacon	11,500		
		Hawk. Grng.	12,143		
		McIntosh	12,000		
		Yel. Del.	12,500		
		Robusta #5	11,875		

environment and that graft combinations should be selected carefully. Some of the superior combinations considering survival, compatibility, and anchorage are given in Table 6.

Table 6 Superior Scion/Interstem/Rootstock Combinations

COMBINATION	COMBINATION
Jonathan/M IX/	Yel. Del./Clark/Bedford
Jonathan/Clark/Dolgo	Yel. Del./M VII/Bedford
Jonathan/Clark/Bedford	Yel. Del./Clark/Dolgo
Jonathan/Clark/Hopa	Yel. Del./M IX/Hopa
Red Del./Clark/Hopa	Winesap/Clark/Bedford
Red Del./Robin/Bedford	Winesap/M IX/Dolgo
Red Del./Clark/Bedford	Winesap/M VII/Bedford
Red Del./M IX/Hopa	Winesap/M VII/Beacon
Red Del./M IX/Bedford	
Red Del./M VII/Bedford	

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Dr. J. P. Mahlstedt, Head, Department of Horticulture, Iowa State University, Ames, Iowa.

MODERATOR SHUGERT: Thank you very much, Don. We now have some time for questions.

MR. JIM WELLS: I would like to ask Dr. Wetherell if he has tried his techniques on other plants in addition to wild carrot?

DR. WETHERELL: There are about 100 plants around the world, both woody and non-woody that have been cultured as tissue cultures. However, the induction of roots and shoots is rather sporadic and only recently have we learned how to do this for the carrot. We are pursuing this, however, with plants such as blueberry, grape, forsythia, cucumber, and geranium. We would like to know what it takes for these plants to regenerate. It may be quite different from the wild carrot.

MR. MARTIN VAN HOF: I would like to ask Dr. White if he would graft a vigorous scion on a dwarf growing stock such as Malling IX.

DR. WHITE: Yes. In fact, we wanted to see if Malling IX as an interstock was as affective as a root stock. It turned out that as an interstock it was not as dwarfing and was intermediate in its dwarfing effect.

MR. ROBERT SIMPSON: Have *Zumi* seedlings ever been used as an understock?

DR. WHITE: I am not sure, but to my knowledge they have not.

MR. SIMPSON: We tried *Zumi* with ornamental crabs. The *Zumi* seedlings make an entirely different root system, a very vigorous root system, and what appears to be a superior system in comparison to *baccata*.

MR. AL LOWENFELS: Has Hans Hess had any success in rooting *Ilex verticillata*?

MR. HANS HESS: There are a number of selections that root well from soft wood cuttings. The Princeton variety roots well. The cuttings are made when they are soft and are treated with Hormodin #3 after the cuttings are wounded.

VOICE: I would like to ask Hans Hess if he uses any artificial treatment for *Ilex opaca* seed?

HANS HESS: We do not use any artificial treatment. At Boyce Thompson Institute they are able to excise the embryo and with special treatment obtain germination the first year. We have found from a commercial stand point that the best treatment is to store the seed for 2 years and then plant it. We store the seed in peat in a metal container with a polyethylene top. It is in an unheated stable so the seed is exposed to low temperatures in the winter and warm temperatures in the summer. However, extreme fluctuations in temperature are reduced by the building.

The source of the seed is very important. Southern seed will germinate the first year, but seed from the northern varieties, which are more hardy, require 2 years for germination.

The session adjourned for the business meeting at 3:00 p.m.