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Field Susceptibility of Scab-Resistant Apple Cultivars and Selections to Cedar Apple Rust, Quince Rust and Hawthorn Rust

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Abstract

Apple cultivars and selections developed from the scab-resistant breeding programs in Ottawa, Ontario; Kentville, Nova Scotia; the disease-resistant breeding program at Geneva, N.Y.; and the cooperative breeding program at the universities of Purdue, Rutgers and Illinois were evaluated under field conditions for resistance to cedar apple rust (CAR), quince rust (QR) and hawthorn rust (HR). Between 1985 and 1989, percent fruit infection on the various cultivars and selections varied from 0 to 98 for CAR and from 0 to 79 for QR. Leaf lesions resulting from HR infection were smaller in diameter and fewer in number than those resulting from CAR infection. Long wetting periods during bud development from the pink to the calyx stage contributed to the infections. The scab-resistant cultivars 'Liberty,' 'Macfree,' 'Moira,' 'Murray,' 'Nova Easygro,' 'Novamac,' 'Priscilla,' 'Redfree,' and 'Trent' exhibited a high level of resistance to CAR. While none of the cultivars and selections were immune to QR, 'Jonafree,' 'Liberty,' 'Redfree,' 'Co-op 1,' 'Co-op 8,' 'Co-op 15,' and 'O-634' had lower levels of infection than did 'McIntosh.'

Introduction

Apple scab caused by *Venturia inaequalis* (Cke.) Wint. is the most serious disease affecting apple, *Malus domestica* Borkh., in apple growing areas of northeastern North America and may require 12 or more fungicide sprays for control. Growing cultivars resistant to apple scab eliminates the need for fungicides for scab control in these growing areas. However, cultivar susceptibility to one or more of the rust diseases attacking the apple may partially decrease the advantage of reduced fungicide requirements for scab-resistant cultivars in some growing areas. Three rust diseases of apple have been identified in eastern North America (18, 22, 26). Cedar apple rust (CAR) caused by *Gymnosporangium juniperi-virginianae* Schw. occurs on both leaves and fruit of apple, hawthorn rust (HR) caused by *G. globosum* Farl. occurs only on leaves, and quince rust (QR) caused by *G. clavipes* Cke. and Pk. occurs on fruit and appears on leaves as non-discrete spots (25).

Apple cultivars resistant to CAR have been identified (1, 7, 9, 19, 21) and the inheritance of resistance has been investigated (3, 7, 20). The disease-resistant breeding program at Geneva, N.Y. has incorporated resistance to CAR as well as resistance to other major diseases into new apple cultivar releases (15). The cooperative apple scab resistant breeding program at the universities of Purdue, Rutgers and Illinois (PRI) has also incorporated resistnce to CAR into some cultivars and selections (10, 11, 28, 29, 30). The scab-resistant breeding program initiated in Ottawa in 1949 (24) did not include resistance to rust diseases, although field evaluation was conducted at the Smithfield Experimental Farm (27). None of the above breeding programs have included deliberate selection for resistance to HR or QR.

This paper reports the field susceptibility to CAR, HR, and QR of scab-resistant apple cultivars and selections derived from the Ottawa (O), PRI, Geneva and Kentville, N.S. breeding programs.

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Materials and Methods

A planting of scab-resistant apple cultivars and selections was established in the spring of 1978 consisting of three trees of each cultivar and selection on each of M.26 and Ottawa 3 rootstocks. Trees were spaced at 2.5 x 4 m without randomization. 'McIntosh' and 'Delicious,' both scab-susceptible, were planted as guard trees along the periphery of the orchard. No fungicides were applied in this orchard. A seasonal insecticide spray program was applied annually, consisting of four to five sprays of azinphos-methyl, phosmet or phosalone, and acaracides for mite control.

A minimum of 100 fruits per cultivar and selection were assessed for CAR and QR infection in late July or early August of 1985, 1986, 1988 and 1989. In 1986, Some culitvars produced less than 100 fruits and therefore all fruits on the six trees were evaluated. In 1987, rust infection was very low and therefore it was not assessed that year.

The two most severely infected leaves on each to ten terminal shoots per cultivar and selection were rated for rust infection in late July or early August of 1986, 1988 and 1989. The number of rust lesions per leaf was estimated using a scale of 0 to 4 (0 = no lesions; 1 = 1 to 5; 2 = 6 to 25; 3 = 26 to 50; 4 = 51 to 100 lesions per leaf) and tr (less than 5 rust lesions per terminal shoot after all leaves on the shoot were examined), and the mean rating for each cultivar and selection was recorded. For each cultivar and selection, the diameter of 10 rust lesions was measured and median lesion diameter was determined. In late August or early September of each year, leaf rust lesions were examined for pycnial or aecial development and the most advanced stage of development was recorded. Based on size of the lesion, number and location of aecia, and shape of the peridium (18, 26), leaf infection was determined to be either CAR or HR. Where aecia were not present or were poorly developed on leaves, no differentiation was made between CAR or HR.

Rust infection occurred from naturally occurring sources. Trees of eastern red cedar, *Juniperus virginiana* L., the alternate host for CAR, HR and QR (22, 26) were growing within 500 to 1000 m of the test orchard.

To determine apple rust infection periods, data on temperature and leaf wetness duration were recorded for each wetting period using a Crop Tech Orchard Monitor (Crop Technologies Inc., Bloomingdale, Ont.). Data on rainfall were collected using a tipping bucket rain gauge (Campbell Scientific, Edmonton, Alberta).

Results and Discussion

Both CAR and HR were observed on leaves of apple cultivars and selections evaluated in this experiment (Table 1). Leaf rust infection was less severe in 1988 and 1989 than in 1986. More variabililty was observed in the number of lesions between leaves and shoots in 1986 as compared to the other two years. Leaf rust ratings in 1988 and 1989 were rounded off to the nearest whole number.

Median lesion diameter on leaves infected with HR was 1 or 2 mm. CAR median lesion diameter was larger, 2 to 6 mm, and only in one case was 1 mm in diameter. For some cultivars and selections, it was difficult to identify the rust species causing the leaf symptoms due to absence or poor development of aecia. For these cultivars and selections, median leaf lesion diameter (usually 1 mm and sometimes 2 mm) and the absence of fruit infection suggests HR infection.

Both CAR and HR infection may occur simultaneously on leaves of some cultivars as reported previously for 'McIntosh' (26, Rosenberger, personal communication) and other cultivars (22). Leaf symptoms of CAR and HR are similar and therefore it is difficult to differentiate and confirm the iden-

Table 1. Susceptibility of scab-resistant apple cultivars to cedar apple rust, *Gymnosporangium juniperi-virginianae*, and hawthorn rust *G. globosum*, at the Smithfield Experimental Farm, 1986, 1988, and 1989.

Cultivar or selection	Leaf rust rating[v]			Median lesion diameter (mm)[w]			Most advanced symptom[x]	Type of leaf rust[y]
	1986	1988	1989	1986	1988	1989		
Britegold	2.5	3	2	3	3	2	A	CAR
Co-op 1	2.2	—	—	1	—	—	P	U
Co-op 3	2.1	—	—	1	—	—	A	U
Co-op 6	2.6	3	2	3	5	4	A	CAR
Co-op 7	1.0	2	0	2	2	—	A	HR
Co-op 8	0.7	0	0	1	—	—	A	U
Co-op 9	2.7	2	2	4	3	3	A	CAR
Co-op 10	2.2	1	1	1	1	1	A	HR
Co-op 11	0.8	1	tr	2	2	1	A	HR
Co-op 12	3.1	3	2	4	4	4	A	CAR
Co-op 14	1.7	1	0	1	2	—	A	HR
Co-op 15	2.4	3	2	4	4	3	A	CAR
Co-op 16	3.0	2	2	3	6	3	A	CAR
Delicious[z]	1.5	0	tr	1	—	1	A	U
Jonafree	2.4	3	2	5	5	4	A	CAR
Macfree	1.5	1	tr	1	2	1	A	U
McIntosh[z]	1.4	tr	tr	1	1	1	A	HR
Moira	2.1	1	tr	1	1	1	A	HR
Murray	1.2	1	0	1	1	—	A	HR
Nova Easygro	1.1	tr	tr	2	2	1	A	HR
Novamac	0.9	tr	0	2	1	—	A	HR
O-521	3.6	3	1	3	5	3	A	CAR
O-533	0.6	0	0	1	—	—	P	U
O-546	1.1	tr	tr	1	1	1	A	HR
O-5410	—	tr	0	—	2	—	A	HR
O-591	—	tr	0	—	1	—	A	HR
O-625	0.6	1	0	2	2	—	A	HR
O-634	0.8	tr	0	1	1	—	P	U
O-637	0.8	tr	0	1	1	—	A	HR
O-638	0.5	0	0	1	—	—	N	U
O-641	1.0	tr	0	1	1	—	A	HR
O-644	0.4	0	0	1	—	—	N	U
O-645	0.5	0	0	1	—	—	N	U
O-648	3.8	3	2	2	3	1	A	CAR
O-6410	0.1	0	0	1	—	—	N	U
O-6413	3.3	2	1	2	3	2	A	CAR
O-6414	0.6	0	0	1	—	—	N	U
O-6415	0.7	tr	tr	1	1	1	N	U
O-6416	0.1	0	0	1	—	—	N	U
O-6417	0.9	0	0	1	—	—	N	U
O-653	0.9	tr	0	1	1	—	A	HR
O-654	0.7	tr	tr	1	1	1	A	HR
O-655	0.9	tr	0	1	2	—	A	U
O-656		tr	0	—	1	—	A	HR
O-661	3.2	2	2	4	5	3	A	CAR

Table 1. (Continued).

Cultivar or selection	Leaf rust rating[v]			Median lesion diameter (mm)[w]			Most advanced symptom[x]	Type of leaf rust[y]
	1986	1988	1989	1986	1988	1989		
O-662	2.1	1	tr	1	1	1	A	HR
O-663	2.2	3	1	2	2	3	A	CAR
O-664	0	0	0	—	—	—		
O-667	—	tr	0	—	1	—	P	U
O-669	1.6	tr	0	1	1	—	A	HR
Prima	3.1	—	—	5	—	—	A	CAR
Priscilla	2.2	2	1	2	1	1	A	HR
Redfree	0.1	0	0	1	—	—	N	U
Richelieu	2.8	3	1	4	4	2	A	CAR
Sir Prize	4.0	4	2	3	3	3	A	CAR
Trent	1.5	tr	tr	1	1	1	A	HR

[v]0 = no lesions, 1 = 1 to 5, 2 = 6 to 25, 3 = 26 to 50, 4 = 51 to 100 rust lesions per leaf, tr = less than 5 rust lesions per terminal shoot and — indicates not evaluated.
[w]Based on 10 lesions per cultivar or selection.
[x]A = aecia, P = pycnia, N = nonsporulating.
[y]CAR = cedar apple rust, HR = hawthorn rust, QR = quince rust, U = undetermined.
[z]scab susceptible.

tity of the disease (1, 18, 26). However, Aldwinckle reported low frequency of occurrence of HR in apple orchards (1) and on *J. virginiana* (Aldwinckle, personal communication) compared to CAR.

Leaf rust ratings were generally higher for CAR than for HR in all years. In 1988 and 1989, CAR susceptible cultivars and selections usually had leaf rust ratings of 2 or 3 (6 to 25 or 26 to 50 lesions per leaf) as compared to ratings of 0, tr or 1 (less than 5 lesions per leaf) for HR susceptible cultivars and selections. Leaf abscission has been reported for leaves having more than five CAR lesions per leaf (12, 20, 23). When rust-susceptible cultivars and selections are grown, serious defoliation and tree decline (12, 13, 23) have been reported from severe rust infection. Premature leaf abscission has also been observed in the Smithfield orchard (27), however, no attempt was made to correlate leaf abscission with rust infection. Since HR does not attack apple fruits (18, 26) and leaf lesions are few and small in diameter (usually less than 2 mm), the commercial fruit grower has little reason to be concerned about HR infection.

A wide range of CAR fruit-susceptibility was observed among cultivars and selections, and among years (Table 2). In general, the highest level of fruit infection was observed in 1986. This was likely due to a 64-hour wetting period that occurred at the calyx stage of bud development (Table 3). In 1985 and 1988, lower levels of fruit infection were observed. Wetting periods of 56 and 44 hours occurred at the calyx stage in 1985 and at the full pink stage in 1988, respectively. In 1989, wetting periods of 11.0 to 25.5 hours occurred between the full pink and calyx stage of bud development, and only low levels of CAR infection were observed. In 1987, a 10-hour wetting period occurred at petal fall, and no rust infection was observed. Although leaf infection from *G. juniperi-virginianae* may occur with leaf wetting periods as short as 2 hours at 20 to 24°C, severe infections were

Table 2. Susceptibility of apple fruits to cedar apple rust, *Gymnosporangium juniperi-virginianae*, and quince rust *G. clavipes*, at the Smithfield Experimental Farm, 1985 to 1989.

Cultivar or selection	Cedar apple rust % fruit infection[x]				Quince rust % fruit infection[x]			
	1985	1986	1988	1989	1985	1986	1988	1989
Britegold	12	64	3	2	1	42	4	0
Co-op 1	0	0	—	—	2	8	—	—
Co-op 3	1	0	—	—	1	26	—	—
Co-op 6	81	66	20	2	5	39	4	0
Co-op 7	0	0	0	0	1	45	13	0
Co-op 8	0	0[y]	2	0	0	10[y]	0	0
Co-op 9	35	41	22	—	14	79	12	—
Co-op 10	0	0	0	0	4	68	3	1
Co-op 11	0	0	0	0	2	68	2	2
Co-op 12	62	94	43	0	3	8	12	1
Co-op 14	0	1	0	0	1	35	4	0
Co-op 15	38	98	20	2	1	11	2	0
Co-op 16	51	57	9	1	6	69	3	0
Delicious[z]	0	0	0	0	1	43	1	2
Jonafree	22	86	4	1	0	7	1	0
Liberty	—	0	0	0	—	5	1	0
Macfree	0	0	0	0	9	31	8	1
McIntosh[z]	0	0	0	0	3	11	2	0
Moira	1	0	0	0	14	44	5	0
Murray	1	0[y]	0	0	12	34[y]	16	3
Nova Easygro	0	—	0	0	2	—	6	1
Novamac	—	0[y]	0	0	—	31[y]	3	0
O-521	—	81	3	12	—	31	3	0
O-533	0	0	0	0	6	16	3	0
O-546	0	0	0	0	1	46	1	0
O-5410	—	—	0	0	—	—	2	1
O-591	—	—	0	0	—	—	2	0
O-625	0	0	0	0	17	51	2	0
O-634	0	0	0	0	2	7	0	0
O-637	0	0	0	0	2	12	4	0
O-638	0	—	0	0	2	—	1	0
O-641	3	0[y]	0	0	4	45[y]	5	0
O-644	0	0	0	0	8	48	11	0
O-645	0	0	0	0	13	31	4	0
O-648	12	31	11	2	8	78	12	0
O-6410	0	0	0	0	5	68	3	1
O-6413	23	52	3	0	6	41	4	0
O-6414	0	0	0	0	2	31	0	0
O-6415	2	0	0	0	5	31	9	0
O-6416	0	0	0	0	0	16	1	0
O-6417	0	0[y]	0	0	5	72[y]	7	0
O-653	0	0[y]	0	0	10	40[y]	23	1
O-654	0	0[y]	0	0	0	30[y]	8	0
O-655	—	—	0	0	—	—	2	0
O-656	—	—	0	0	—	—	2	0

Table 2. (Continued).

Cultivar or selection	Cedar apple rust % fruit infection[x]				Quince rust % fruit infection[x]			
	1985	1986	1988	1989	1985	1986	1988	1989
O-661	27	86	24	0	6	76	11	1
O-662	0	0	0	0	0	41	2	0
O-663	39	75	21	0	4	42	0	0
O-664	0	0	0	0	0	53	8	1
O-667	—	—	0	0	—	—	3	0
O-669	—	—	0	0	—	—	3	0
Prima	72	91	—	—	2	19	—	—
Priscilla	0	0	0	0	10	33	0	1
Redfree	1	0	0	0	4	6	1	0
Richelieu	22	61	17	1	5	12	2	1
Sir Prize	84	52	12	5	15	58	2	3
Trent	4	0	0	0	6	41	4	1

[x]— indicates not evaluated.
[y]Less than 100 fruits examined.
[z]Scab-susceptible.

observed at leaf wetting periods of 5 hours or longer at 16-22°C and 7 hours or longer at 10 to 22°C (4). Aldwinckle *et al.* (4) suggested that the period of maximum fruit susceptibility occurred from early pink through full bloom. The present study also indicates that long wetting periods from the pink to the calyx stage are most likely to result in high incidence of fruit infection under field conditions. Rosenberger (personal communication) indicated that long wetting periods are more likely to result in infection when the orchard was farther away from the source of infection since basidiospores can travel longer distances during long wetting periods.

Genetic studies have shown that two major genes along with minor modifying genes are responsible for conferring resistance to CAR (3, 7, 20). Interaction of physiological strains of *G. juniperi-virginianae* with the environment is also involved in CAR resistance (2, 3, 7, 14).

Many of the scab-resistant cultivars and selections from the Ottawa (O) apple breeding program have 'McIntosh,' (CAR-resistant cultivar) in their parentage. These include 'Macfree,' 'Moira,' 'Murray,' 'Trent,' 'O-533,' 'O-546,' 'O-5410,' 'O-591,' 'O-625,' 'O-634,' 'O-637,' 'O-638,' 'O-655,' 'O-667,' and 'O-669,' all of which are resistant to CAR. In addition, 'Co-op 10,' 'Liberty,' 'Nova Easygro,' 'Novamac,' and 'Priscilla' also have 'McIntosh' in their parentage and are also resistant to CAR. However, 'Richelieu' and 'O-663' were susceptible to CAR although they have 'McIntosh' in their background. Selections resulting from the crosses 'O-527' x 'Lobo' ('McIntosh' seedling), 'O-522' x 'Sandel,' and 'O-521' x 'Delicious' showed a mixed reaction to CAR (Table 4). However, 'O-653' and 'O-656,' resulting from the cross 'O-522' x 'Lindel,' were resistant to CAR, indicating that sources of resistance to CAR other than 'McIntosh' are present in the Ottawa scab-resistant selections.

Our results generally agree with those reported elsewhere. 'Prima' and 'Sir Prize,' found susceptible to CAR were also reported susceptible in New York (2, 3, 5), Massachusetts (6) and Illinois (7). Similarly, 'Jonafree,' found susceptible to CAR was also reported susceptible in Illinois (7) and leaf rust lesions were reported in Massachusetts (16). 'Delicious,' 'Liberty,' 'McIntosh,' 'Nova Easygro,' 'Priscilla,' 'Redfree,' and 'Co-op 10,' were all found resistant

Table 3. Stage of bud development, hours of leaf wetness, average temperature and rainfall for apple rust infection periods at the Smithfield Experimental Farm, 1985 to 1989.

Date	Stage of bud development	Leaf wetness (hours)	Average temperature (°C)	Rainfall (mm)
1985				
May 4-6	Tight Cluster	37	8.5	10.6
May 20	Petal fall	14	9.9	5.0
May 26-28	Calyx	56	12.8	36.0
June 1	Post-calyz[z]	22.5	15.0	32.2
1986				
May 16	Petal fall	17	15.0	5.2
May 18-21	Calyx	64	10.5	57.8
May 22-23	Post-calyx[z]	18.5	13.0	2.0
June 1	Post-calyx[z]	9.5	12.0	3.6
1987				
May 14-15	Petal fall	10	14.5	8.0
May 22-23	Post-calyx[z]	19	15.5	5.5
May 26-28	Post-calyx[z]	31	15.8	4.6
1988				
May 16	Pink	12	13.5	3.5
May 18-20	Full pink	44	14.5	22.5
June 1	Calyx	10	17.5	2.6
June 3	Post-calyx[z]	6	12.5	7.7
1989				
May 20-21	Full pink	17.5	15.5	8.0
May 26	Full bloom	11	17.5	4.9
May 30-31	Calyx	25.5	16.4	4.6
June 2	Post-calyx[z]	9.5	17.8	22.4
June 4	Post-calyx[z]	13	15.7	6.3

[z]Post-calyx = early fruit set (1 to 2 weeks after petal fall).

to CAR, similar to other reports (2, 3, 5, 6, 7, 15, 16, 30). 'Co-op 12,' however, was susceptible to CAR in the present study but was reported resistant by Chen and Korban (7). CAR leaf lesions were reported on 'Macfree' (6, 16) and 'Priscilla' (16), however, this might be due to infection with HR rather than CAR. 'Sir Prize' (29) and 'Co-op 16' (28) were reported moderately resistant to CAR when evaluated in field trials in Indiana, and Dayton *et al.* (11) reported no CAR on 'Jonafree' in field trials in Illinois. While the Indiana and Illinois results are contradictory to those of the present study and other published reports (5, 6, 7, 16), this might be explained by a lower inoculum level or lower disease pressure than present in other studies. The performance of apple cultivars in different regions may also be explained by regional variation in physiological races of *G. juniperi-virginianae* (2, 7, 14). In a study carried out by Aldwinckle (2) comparing collections of *G. juniperi-virginianae* from 12 regions in U.S. and Canada, the collection made from Ontario, Canada had the widest host range while the collections made from Indiana and Michigan had the most restricted host range. In addition, a

Table 4. Reaction of scab-resistant selections to cedar apple rust infection in the field.

Parentage and selection	Fruit infection[x] (%)
O-527[y] x Lobo	
O-641	3
O-644	0
O-645	0
O-648	31
O-6410	0
O-6413	52
O-6414	0
O-6415	2
O-6416	0
O-6417	0
O-522[y] x Sandel	
O-654	0
Britegold	64
O-521[y] x Delicious	
O-661	86
O-662	0
O-664	0

[x]Maximum percent fruit infected, 1985 to 1989.
[y]O-527, O-522 and O-521 are selections derived from (Red Melba Platts x R6T68 (Jonathan x (Rome Beauty x *M. floribunda* 821 Sieb.))).

change in the pathogenicity of these physiological races over time has been reported (14).

Fruit infection from *G. clavipes* was severe in 1986. All cultivars and selections were susceptible with percent fruit infection ranging from 5 to 79%. QR was less severe in 1985 and 1988, and susceptible cultivars and selections had up to 23% fruit infection. In 1989, most cultivars were free of QR infection, and only 3% infection was observed on some cultivars and selections.

While the infection process for *G. clavipes* on apple has not been studied in detail, it is considered to be similar to that of *G. juniperi-virginianae* (25, 26). Fruit infection data from the present study supports earlier findings suggesting that conditions resulting in severe CAR infection (1986) also caused severe QR infection, and vice versa. Miller (18) reported that the dissemination period for *G. clavipes* basidiospores was relatively short compared to *G. juniperi-virginianae*. and apple fruits were susceptible to infection by *G. clavipes* for only 12 days when fruits were small in size. Our observations indicate that wetting periods as early as the pink stage may also result in considerable fruit infection from *G. clavipes*.

The level of QR infection reported in the present study was similar to that reported by Coulombe *et al.* (8) in La Pocatiere, Quebec in 1979 where fruit infection of 'McIntosh' ranged from 1 to 20% and 'O-521' was up to 21%. In other years from 1972 to 1980, 'Delicious,' 'McIntosh,' 'Prima,' 'Trent,' 'Co-op 1,' 'O-521' and 'O-546' had 0 to 10% fruit infection (8). Miller (18) reported 40% QR infection on 'Delicious' fruits in an orchard in Tennessee, while Thomas (25) reported 65% and 59% fruit injury on 'Delicious' and 'McIntosh' fruit, respectively, in the Hudson Valley of New York State. In the present study, 43% and 11% of 'Delicious' and 'McIntosh' fruit were infected with QR during 1986. 'Delicious' is usually considered more susceptible to QR than 'McIntosh' (1).

Fruit drop from QR infection was observed on many cultivars and selections in 1986 and on 'Murray' in 1988. Early fruit drop from QR infection has previously been reported in New York State (22, 23, 26) and Quebec (Coulombe, personal communication). Yield reductions from QR infection could occur on highly susceptible cultivars during epidemic years.

None of the cultivars or selections tested were immune to QR, however, 'Jonafree,' 'Liberty,' 'Redfree,' 'Co-op 1,' 'Co-op 8,' 'Co-op 15,' and 'O—634' had lower levels of infection than 'McIntosh' over four years. All, except 'Jonafree' and 'Co-op 15,' also had high levels of resistance to CAR. 'Macfree,' 'Moira,' 'Murray,' 'Novamac,'

'Priscilla' and 'Trent' were resistant to CAR, but susceptible to QR. Based on these studies, there appears to be no genetic linkage between CAR and QR resistance.

This report shows the relative susceptibility of various cultivars and selections to the rust diseases over a five year period. The cultivars and selections may have different levels of susceptibility under different environmental conditions and/or inoculum loads as well as physiological races of the pathogen. Cultivars and selections which are resistant to apple scab differ in susceptibility to the different rust diseases. It is important that apple breeding programs continue to incorporate multiple disease resistance into new cultivar introductions, and screening for fruit diseases should also be conducted.

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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

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[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.