

Field Susceptibility of Scab-Resistant Apple Cultivars and Selections to Cedar Apple Rust, Quince Rust, and Frogeye Leaf Spot

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Abstract

Thirty-seven scab-resistant apple cultivars and selections were evaluated in the field for level of susceptibility to cedar apple rust (CAR), *Gymnosporangium juniperi-virginianae* Schw., quince rust (QR), *G. clavipes* Cke. and Pk., and frogeye leaf spot (FLS), *Botryosphaeria obtusa* (Schw.) Shoemaker. Between 1994 and 1996, fruit infection from CAR varied from 0 to 40% for the various cultivars and selections. The selections originating from the Geneva, N.Y. breeding program were resistant to CAR or had low levels of fruit infection (0-3%). They also had low leaf rust ratings (0 to 0.3) except for NY 74828-12 which had leaf rust ratings of 0.2 to 1.3 (1-25 lesions per leaf) over the three years. The Quebec apple selections (QAS) from Agriculture and Agri-Food Canada, St. Jean, Quebec also had low levels of fruit infection from CAR (0 to 3%). However, several selections did have leaf rust lesions. Other cultivars and selections with field resistance to CAR included 'Moira,' 'Novamac,' 'Redfree,' 'William's Pride,' Co-op 26, O-637 and 547-25-52. QR infection varied from 0 to 31% with 'Moira,' CBR4T29, Co-op 24, QAS-04, QAS-11 and O-661 being most susceptible with fruit infection of 10% or higher. FLS occurred on all cultivars. Those with 5 or fewer lesions per leaf over the three years included 'Dayton,' 'Jonafree,' 'Novaspy,' CBR4T29, Co-op 12, Co-op 15, Co-op 19, Co-op 20, Co-op 24, QAS-01, QAS-03, NY 75414-1 and O-661. In this trial, QAS-01 and NY 75414-1 had combined resistance to all three diseases.

Introduction

The breeding of apples, *Malus X domestica* Borkh., resistant to scab, *Venturia inaequalis* (Cke.) Wint., has resulted in the release of 48 scab-resistant cultivars worldwide between 1970 and 1992 (1). Breeding for multiple disease resistance is now an objective of several breeding programs in North America (2, 4, 5). The field susceptibility of scab-resistant apple cultivars and selections to CAR, hawthorn rust (HR), *G. globosum* Farl., and QR was reported in 1990 (12) and for FLS in 1991 (13). Since then, additional cultivars and breeding selections have been evaluated in the field for susceptibility to the diseases.

This paper reports the field susceptibility to CAR, QR and FLS of scab-resistant apple cultivars and selections during the three year period from 1994 to 1996. Cultivars which were previously shown to be susceptible to the diseases were included for comparison.

Materials and Methods

A planting of scab-resistant apple cultivars and selections was established in the spring of 1989 at the Smithfield Research Farm (SRF), Trenton, Ontario. The planting consisted 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. Cultivars and selections previously tested for susceptibility to CAR, QR and FLS were mixed within the experimental area (12, 13). Selections derived from the Agriculture and Agri-Food Canada breeding programs at St. Jean, Quebec (QAS series); Kentville, N.S. (S series); the former breeding program at Ottawa, Ontario (O series); the cooperative breeding program at the universities of Purdue, Rutgers and Illinois (Co-op series and CBR4T29); and Geneva, N.Y. (NY series) were evaluated.

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Table 1. Susceptibility of scab-resistant apple cultivars and selections to cedar apple rust, *Gymnosporangium juniperi-virginianae* at the Smith-field Research Farm, Trenton, Ontario, 1994, 1995 and 1996.

Cultivar or selection	Leaf rust rating ^w			Median lesion diameter (mm) ^x			Most advanced symptom ^y	Type of leaf rust ^z
	1994	1995	1996	1994	1995	1996		
Dayton	1.3	1.6	0.9	4	4	3	A	CAR
Jonafree	1.9	2.0	1.2	3	5	3	A	CAR
Moira	0.5	0	0.4	1	0	1	P	U
Novamac	0.3	0	0.4	1	0	1	P	U
Novaspy	1.6	2.8	1.0	5	7	3	A	CAR
Redfree	0	0	0	0	0	0		
William's Pride	0	0	0.6	0	0	1	P	U
CBR4T29	2.0	1.9	1.0	3	5	3	A	CAR
Co-op 9	1.2	1.7	1.2	4	5	5	A	CAR
Co-op 12	1.5	1.7	1.0	3	5	3	A	CAR
Co-op 15	1.7	2.1	1.6	5	4	4	A	CAR
Co-op 16	1.7	2.1	0.9	2	2	3	A	CAR
Co-op 19	0.8	1.7	0.8	2	2	1	A	CAR
Co-op 20	1.0	1.5	1.0	2	5	2	A	CAR
Co-op 24	1.6	2.3	0.8	2	3	2	A	CAR
Co-op26	0.9	0.5	1.0	1	1	2	P	U
QAS-01	1.9	1.8	1.0	2	2	2	A	U
QAS-03	1.5	2.1	0.9	2	3	2	A	CAR
QAS-04	1.3	0	0.5	1	0	1	N	U
QAS-05	0	0	0.9	0	0	1	P	U
QAS-07	0	0	0.1	0	0	1	N	U
QAS-10	0	0	0.1	0	0	1	N	U
QAS-11	0	0	0.4	0	0	1	P	U
QAS-12	0	0	0	0	0	0		
NY 65707-19	0	0	0.1	0	0	1	N	U
NY 66305-139	0	0	0.1	0	0	1	P	U
NY 66305-289	0	0	0.3	0	0	1	P	U
NY 66325-139	0	0	0.2	0	0	1	P	U
NY 73334-35	0	0	0.1	0	0	1	N	U
NY 74828-12	1.3	0.2	1.0	1	1	2	P	U
NY 74840-1	0	0	0.2	0	0	1	N	U
NY 75414-1	0	0	0.1	0	0	1	P	U
NY 75441-67	0	0	0	0	0	0		
O-637	0	0	0.7	0	0	1	N	U
O-661	1.9	2.1	1.2	4	7	4	A	CAR
S34-22-49	2.0	2.6	1.3	7	4	3	A	CAR
S47-25-52	0	0	0.1	0	0	2	P	U

^w0 = no lesions, 1 = 1 to 5, 2 = 6 to 25, 3 = 26 to 50 rust lesions per leaf.

^xBased on 10 lesions per cultivar or selection.

^yA = aecia, P = pycnia, N = nonsporulating.

^zCAR = cedar apple rust, U = undetermined.

No fungicides were applied in this orchard. A seasonal insecticide spray program was applied annually, consisting of four to five sprays of azinphos-methyl or phosmet 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 1994 to 1996. Some cultivars produced less than 100 fruits and therefore all fruits on the six trees were evaluated.

The two most severely infected leaves on each of ten shoots per cultivar and selection were rated for rust and FLS infection in late July or early August of 1994 to 1996. The number of rust or FLS lesions per leaf was estimated using a scale of 0 to 3 (0 = no lesions, 1 = 1 to 5, 2 = 6 to 25, 3 = 26 to 50 lesions per leaf) and the mean rating for each cultivar and selection was determined. For each cultivar and selection, the diameter of 10 rust lesions was measured and median lesion diameter was determined. In late August (1996) or mid-September (1994 and 1995), leaf rust lesions were examined for pycnial or aecial development and for the most advanced stage of development. Where possible, CAR was identified based on the size of the lesion and number and location of the peridium (6, 11). Where aecia were not present or poorly developed on the leaves, no identification of rust species was made.

Rust infection occurred from naturally occurring sources. Trees of eastern red cedar, *Juniperus virginiana* L., the alternate host for CAR, HR and QR (7, 11) were growing along fence rows and in wooded areas within 800 to 1000 m to the west of the test orchard and within 500 m to the south, north and northeast of the test orchard. The prevailing winds were from the west.

Results and Discussion

Of 37 cultivars and selections tested, 14 were rated as susceptible to CAR (Table 1). The highest leaf rust rating obtained over the three year period from 1994 to 1996 was 3 (26-50 rust lesions per leaf). 'Jonafree,' Co-op 12, Co-op 15 and O-661, identified as susceptible to CAR in

1990 (12), were included in this study for comparison. NY selections were screened for resistance to CAR before release (4) and had low leaf rust ratings (0 to 0.3) except for NY 74828-12 which had a rating of 0.2 to 1.3, depending on year. Median lesion diameter for CAR on leaves varied from 2 to 7 mm and only in one case (Co-op 19) was 1 mm.

For other cultivars and selections, it was difficult to identify the rust species causing leaf symptoms due to absence or poor development of aecia. A median lesion diameter of 1 to 2 mm and absence or very little fruit infection suggests HR infection. 'Moirá,' 'Novamac' and O-637 were previously reported as susceptible to HR with 1 to 2 mm diameter lesions (12) similar to the lesion size of 1 mm in the present study. Since HR does not attack the apple fruits (6, 11) and leaf lesions tend to be fewer in number and smaller in diameter than CAR (12), the commercial fruit grower has little reason to be concerned about HR infection.

CAR fruit infection was more prevalent in 1995 and 1996 than in 1994. The most susceptible cultivars with over 10% fruit infection were 'Jonafree,' 'Novaspy,' Co-op 9, Co-op 12, Co-op 15, Co-op 16, Co-op 24, O-661 and 834-22-29 (Table 2). Other cultivars susceptible to CAR leaf infection but with less than 10% fruit infection were 'Dayton,' CBR4T29, Co-op 19, Co-op 20 and QAS-03. 'Williams Pride,' considered field immune to CAR (1), had only 1% fruit infection in 1996. NY 73334-35 had 3% fruit infection and a leaf rust rating of 0.1 in 1996. NY 74828-12 and QAS-01 with 1 and 3% CAR fruit infection, respectively, had leaf rust ratings of 0.2 to 1.3 and 1.0 to 1.9, respectively, depending on year.

The results for susceptibility of Co-op selections to CAR agrees with ratings reported by Crosby et al. (1) except that they reported Co-op 19 as highly resistant to CAR. Co-op 19 was susceptible to both leaf and fruit infection in the present study.

Fruit infection from *G. clavipes* was greater in 1996 compared to the two pre-

Table 2. Susceptibility of apple fruits to cedar apple rust, *Gymnosporangium juniper-virginianae*, and quince rust, *G. clavipes*, at the Smithfield Research Farm, Trenton, Ontario, 1994, 1995 and 1996.

Cultivar or selection	Cedar apple rust (% fruit infection)			Quince rust (% infection)		
	1994	1995	1996	1994	1995	1996
Dayton	2	1	2	0	3	1
Jonafree	0*	14	20*	0*	0	0
Moir	0	0	0	0	0	11
Novamac	0	0	0	0	0	4
Novaspy	1*	40	5*	0*	3	7*
Redfree	0	0	0	0	0	2
William's Pride	0	0	1	0	0	4
CBR4T29	3	0	0	0	0	10
Co-op 9	3*	13	-	0*	1	-
Co-op 12	1	22	35	0	0	5
Co-op 15	1	37	23*	0	0	3*
Co-op 16	0	13	-	0	0	-
Co-op 19	0	6	1*	0	1	8*
Co-op 20	2*	6	5	0*	0	0
Co-op 24	1	4	12	0	0	31
Co-op 26	0*	0	0	0*	2	7
QAS-01	0*	3	0	0*	0	2
QAS-03	2	3	0	0	0	3
QAS-04	0	0	0	0	0	19
QAS-05	0	0	0	0	0	9
QAS-07	0	0	0	0	0	0
QAS-10	0	0	0*	0	0	0*
QAS-11	0	0	0*	0	1	26*
QAS-12	0*	0	0	0*	0	2
NY 65707-19	0	0	0*	1	1	6*
NY 68305-139	0*	0	0	0*	0	1
NY 66305-289	0*	0	0	3*	0	3
NY 66325-139	0*	0	0*	0*	0	1*
NY 73334-35	0	0*	3*	0	0*	7*
NY 74828-12	1	0	0*	0	0	2*
NY 74840-1	0*	0	0	0*	0	2
NY 75414-1	0	0	0	0	1	3
NY 75441-67	0*	0	0	2*	0	3
O-637	0*	0	-	0*	0	-
O-661	1*	37	30*	0*	5	12*
S34-22-49	3	20	1*	0	3	0*
S47-25-52	0*	0	0*	0*	1	0*

* Less than 100 fruits examined.

- No fruit.

vious years (Table 2). Fruit infection varied from 0 to 31% which was less than the 5 to 79% level of infection which occurred in 1986 (12). 'Jonafree,' 'Redfree'

and Co-op 15 had lower levels of fruit infection compared to 'McIntosh' in the 1990 study (12) and had 0, 2 and 3% QR fruit infection, respectively, in the present

study. The NY selections and several of the QAS which were resistant to CAR had varying levels of QR infection to the fruit (Table 2).

FLS is considered an important disease affecting scab-resistant cultivars (3, 10, 13) because of the absence of fungicides normally used to control scab on scab-susceptible cultivars which also controlled FLS. In this study, a range in cultivar susceptibility to FLS occurred over the 3 years (Table 3). 'Redfree' which had a leaf spot rating of 3 (26 to 50 lesions per leaf) in 1988 and a rating of 2 (6 to 25 lesions per leaf) in 1989 and 1990 (13) was equally susceptible in the present study with a rating of 2 to 2.1. Rosenberger (10) suggested that ratings with more than 5 spots per leaf would be unacceptable in commercial orchards. Cultivars and selections with 5 or fewer lesions per leaf included 'Dayton,' 'Jonafree,' 'Novaspy,' CBR4T29, Co-op 9, Co-op 12, Co-op 15, Co-op 19, Co-op 20, Co-op 24, QAS-01, QAS-03, NY 75414-1 and O-661. 'Jonafree,' Co-op 12, Co-op 15 and O-661 also had low FLS ratings during the period from 1988 to 1990 (13).

Previous results (12, 14 and unpublished data) evaluating apple cultivars for susceptibility to rust diseases showed that infection occurred on susceptible cultivars throughout plantings at the SRF. Basidiospores are discharged from infections on the alternate host, *J. virginiana* (8, 11), which were located along and outside the perimeter of the 120 ha SRF. The spores, carried by wind and air currents for several miles, eventually settled on apple leaves and fruit (8, 9). Because the experimental orchard was not located adjacent to the alternate host, sufficient mixing of basidiospores with air currents occurred to provide uniform inoculum distribution over the test area. Conidia of *B. obtusa*, the causal agent of FLS, likely originated from dead twigs and fruit mummies from within the orchard (7), providing uniform inoculum levels.

This report shows the relative susceptibility of scab-resistant cultivars and selections to the rust diseases and FLS over a

Table 3. Susceptibility of scab-resistant apple cultivars and selections to frogeye leaf spot, *Botryosphaeria obtusa*, at the Smithfield Research Farm, Trenton, Ontario, 1994, 1995 and 1998.

Cultivar or selection	Frogeye leaf spot rating ²		
	1994	1995	1996
Dayton	0.8	0	0.2
Jonafree	0.3	0	0
Moira	1.2	1.7	1.0
Novamac	1.4	1.4	0.8
Novaspy	0.8	0	0
Redfree	2.0	2.1	2.0
William's Pride	1.1	1.1	0.3
CBR4T29	0.4	0	0
Co-op 9	1.0	0.1	0.1
Co-op 12	0.8	0.2	0
Co-op 15	0.2	0.1	0
Co-op 16	1.1	0.8	0.9
Co-op 19	0.9	0.8	0.3
Co-op 20	0.8	0.5	0.2
Co-op 24	0.7	0.1	0.1
Co-op 26	1.5	1.4	0
QAS-01	0.1	0	0.1
QAS-03	0.8	0	0
QAS-04	1.1	1.6	0.7
QAS-05	1.0	1.2	0.9
QAS-07	1.5	0.8	0.1
QAS-10	1.8	1.3	0.9
QAS-11	1.2	1.7	0.8
QAS-12	1.1	1.2	1.0
NY 65707-19	1.9	1.8	0.9
NY 66305-139	1.2	1.6	0.1
NY 68305-289	1.8	1.9	0.8
NY 66325-139	1.6	2.1	1.4
NY 73334-35	1.0	1.5	0.9
NY 74828-12	1.1	1.0	1.0
NY 74840-1	1.7	0.7	0.8
NY 75414-1	0.7	0.2	0.4
NY 75441-67	1.0	1.4	0.9
O-637	1.1	1.7	0.9
O-661	0.8	0.3	0
S34-22-49	1.1	0.2	0.1
S47-25-52	1.2	1.6	0.8

²0 = no lesions, 1 = 1 to 5, 2 = 6 to 25, 3 = 26 to 50 lesions per leaf.

three year period. The cultivars and selections may have different levels of susceptibility under different environmental conditions and/or inoculum loads. The breeding program at Geneva, NY has

been successful in releasing selections which are field resistant to CAR. Although breeding programs are not specifically addressing QR and FLS, there is a range in cultivar susceptibility to these diseases. In this trial, QAS-01 and NY 75414-1 had the best combination of resistance to all three diseases with 0 to 3% fruit infection from CAR or QR and fewer than 5 FLS lesions per leaf.

Literature Cited

1. Crosby, J. A., J. Janick, P. C. Pecknold, S. S. Korban, P. A. O'Connor, S. M. Ries, J. Goffreda and A. Voordeckers. 1992. Breeding apples for scab resistance: 1945-1990. *Fruit Var. J.* 46:145-166.
2. Dayton, D. F., J. B. Mowry, E. B. Williams, J. Janick, F. H. Emerson, L. F. Hough and C. Bailey. 1977. Scab-resistant apples. *HortScience* 12: 434.
3. Granger, R. L., S. Khanzadeh and O. Carisse. 1994. Promising scab resistant apple selections for Quebec, Canada. *Fruit Var. J.* 4:41-42.
4. Lamb, R. C., H. S. Aldwinckle, R. D. Way and D. E. Terry. 1978. Liberty, a new disease resistant apple. *N.Y. State Agric. Exp. Stn. Food and Life Sd. Bull.* 73. 2 pp.
5. Merwin, I. A., S. K. Brown, D. A. Rosenberger, D. R. Cooley and L. P. Beckett. 1994. Scab-resistant apples for the northeastern United States: new prospects and old problems. *Plant Disease* 78:4-10.
6. Miller, P. R. 1939. Pathogenicity, symptoms and the causative fungi of three apple rusts compared. *Phytopathology* 29:801-811.
7. Miller, P. M. and S. L. Anagnostakis. 1973. Piles of apple prunings as sources of conidia of *Physalospora obtusa*. *Phytopathology* 83:1080.
8. Palmer, D. H. 1952. Rust diseases of apples and their control in the Hudson Valley. *N.Y. State Agric. Exp. Stn. Bull.* 756. 26 pp.
9. Palmer, D. H. 1954. Rust diseases of apple. Pages 658-663 in: *U.S. Dept. Agric. Yearb. Agric.* 1953.
10. Rosenberger, D. A., F. W. Meyer and C. A. Engle. 1994. Rust-induced leaf spots and powdery mildew on scab-resistant apple cultivars are affected by planting location. *Northeast Sustainable Apple Production Newsletter.* 5:1-3.
11. Thomas, H. E. and W. D. Mills. 1929. Three rust diseases of the apple. *Cornell Univ. Agric. Exp. Stn. Memoir* 123. 21 pp.
12. Warner, J. 1990. Field susceptibility of scab-resistant apple cultivars and selections to cedar apple rust, quince rust and hawthorn rust. *Fruit Var. J.* 44:216-224.
13. Warner, J. 1991. Field susceptibility of scab-resistant apple cultivars and selections to frogeye leaf spot. *Can. Plant Dis. Surv.* 71:165-167.
14. Warner, J. 1992. Field susceptibility of 68 apple cultivars to cedar apple rust, quince rust and hawthorn rust. *Fruit Var. J.* 46:6-10.

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Significant contributions to the science and practice of pomology other than fruit breeding will also be considered. Such contributions may relate to any important area of fruit production such as rootstock development and evaluation, anatomical and morphological studies, or unusually noteworthy publications in any of the above subject areas.

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