Components of Partial Resistance to Black Spot Disease (*Diplocarpon rosae* Wolf) in Garden Roses

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Abstract. Eleven rose (*Rosa* spp.) cultivars and advanced lines from the Morden rose breeding program were tested in controlled conditions for five components of partial resistance to two isolates of *Diplocarpon rosae* Wolf, the causal agent of black spot. The isolates were collected from diseased rose leaves in 1995 at Morden, Man., and in Ottawa, Ont. The components examined include incubation period (IP), leaf area with symptoms (LAS), number of lesions (NL), lesion length (LL), and sporulation capacity (SC). Differences in cultivar responses were found for all components. Of the 11 rose genotypes, no visible symptoms developed on line 91V8T201 even at 14 days after inoculation. This line was considered completely resistant to the two isolates tested. X6, T5, and 'Prairie Joy' had a high level of partial resistance. N3 and 'Cuthbert Grant' were intermediate. The remaining five cultivars or lines exhibited a low level of partial resistance. Linear correlations among LAS, IP, NL, and LL were high. Correlations between SC with IP, NL, or LL were nonsignificant. Although each of the five components can be used in selection for partial resistance, any one component may not represent the complete potential for a particular rose genotype. Results of this study suggest that LAS and SC are preferable as criteria for resistance to minimize the labor requirement when evaluating large numbers of rose genotypes in the greenhouse.

Black spot caused by *Diplocarpon rosae* Wolf is a destructive disease of many *Rosa* species and hybrids, including the common tetraploid garden roses (Horst, 1995). Severe infection can result in a total defoliation, dieback of canes, and increased winter injury (Jenkins, 1955; Lyle and Massey, 1941; McClellan, 1953). The most effective measure to control black spot is the use of resistant cultivars. Resistance to this disease has been a criterion for new cultivar development in Canada for many years (Svejda and Bolton, 1980). Several rose genotypes such as 'Jens Munk', 'Martin Frobisher', G49, and L26 have been identified with resistance to black spot and used as sources of resistance in breeding programs. However, the resistance in these cultivars has generally been conferred by specific genes, and often has been short-lived, due to the emergence of corresponding pathogenic races in the pathogen populations (Bolton and Svejda, 1979). Attention has therefore shifted to a race-nonspecific and polygenic type of resistance, i.e., partial resistance. Partial resistance suppresses the rate of epidemic development of a pathogen despite a susceptible infec-

tion type (Parlevliet, 1981). Pathogen populations presumably do not adapt to this type of resistance (Fry, 1982), which is therefore more durable and desirable for use in breeding for black spot-resistant garden roses.

Selection for partial resistance can be a complicated process, since resistance may be expressed as one or many different components of the pathogenic life cycle, such as spore germination, penetration, incubation period, colonization, and sporulation (Zadoks and Schein, 1979). Genotypic differences in components of partial resistance have been reported for several pathosystems, such as barley (*Hordeum vulgare* L.) resistance to *Puccinia hordei* (Neervoort and Parlevliet, 1978) and *Rhynchosporium secalis* (Xue and Hall, 1991), wheat (*Triticum* spp.) resistance to *Puccinia recondita* f.sp. *tritici* (Shaner and Hess, 1978), and bean (*Phaseolus vulgaris* L.) resistance to *Uromyces appendiculatus* (Statler and McVey, 1987). In the rose-black spot pathosystem, host genotypes have not been examined for their differences in components of partial resistance.

To gain a better understanding of interactions between host and pathogen in developing an effective resistance breeding program, partial resistance components of rose genotypes must be examined. This study was carried out to make a preliminary evaluation of five components that might allow the detection of differences in level of resistance to *D. rosae* isolates among 11 rose cultivars and advanced lines. The most effective components in determining partial resistance to black

spot in roses then could be used for screening seedlings in a breeding program aimed at developing stable resistance.

Materials and Methods

Rose plants. Six garden rose cultivars and five advanced lines from the Morden breeding program that were known for different levels of resistance to black spot in preliminary field tests (C.G. Davidson, unpublished) were used in this study. All genotypes were tetraploids and had different hybrid origins (Table 1). Cuttings from field-grown donor plants were rooted under intermittent mist, potted in 14-cm-diameter pots containing a mixture of 1 loam soil : 1 peat : 1 perlite (by volume) and grown in a greenhouse at the Agriculture and Agri-Food Canada (AAFC)-Morden Research Centre, Morden, Man. Greenhouse temperatures ranged from 20 to 25 °C day/18 to 20 °C night. Supplemental light was provided by 300-W metal halide lamps to ensure a 16-h photoperiod and a minimum photosynthetic photon flux (PPF) of 360 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$. Plants were watered with a 1% solution of 20N–20P–20K fertilizer twice a week for ≈ 10 weeks. Prior to inoculation, the plants were moved to a growth room at 20 °C with a 14-h photoperiod at a PPF of 360 $\mu\text{mol}\cdot\text{m}^{-2}\cdot\text{s}^{-1}$ provided by cool-white fluorescent and incandescent lamps. Plants were kept in the same growth room after inoculation.

Pathogen isolates. *Diplocarpon rosae* was isolated from diseased rose leaves collected in 1995 at Morden, Man., and in Ottawa. Single spore isolates from the respective locations were given the corresponding codes MO952 and OT953.

To isolate the pathogen, pieces of leaves ($\approx 4\text{ mm}^2$) with black spot lesions were surface sterilized in 1% sodium hypochlorite for 90 s, rinsed in sterile distilled water, and placed on potato dextrose agar (PDA) in 9-cm-diameter petri dishes. They were incubated for 21 d at 20 °C under cool-white fluorescent lamps with a 14-h photoperiod. Spores from small ($\approx 4\text{ mm}$ in diameter), pinkish colonies of *D. rosae* that developed from the leaf pieces were suspended in drops of sterile distilled water, spread on 2% water agar, and incubated as described above for 24 h. Germinated spores were individually transferred to fresh PDA plates and incubated in the same conditions for 4 weeks.

To prepare inoculum, conidia from 4-week-old cultures on PDA were recovered in sterile distilled water. The spore suspension was adjusted to $\approx 10^7$ conidia per mL with a haemocytometer, and 1 mL was spread over the surface of PDA in 9-cm petri dishes. The dishes were incubated as above for an additional 4 weeks. Each dish then received 10 mL of sterile distilled water containing 0.01% Tween 20 (polyoxyethylene sorbitan monooleate), and rubbed gently with a sterile, latex-tipped glass rod to dislodge spores. The resulting spore suspension was filtered through two layers of cheesecloth and adjusted to 10^5 conidia per mL for inoculations.

Inoculation. Plants were inoculated ≈ 10 weeks after rooting of cuttings. At this time,

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Table 1. Pedigrees of 11 garden rose genotypes tested for components of partial resistance to *Diplocarpon rosae* isolates.

Genotype	Parentage
Cuthbert Grant	[Crimson Glory x (Donald Prior ² x <i>R. arkansana</i>)] x Assiniboine
Hope for Humanity	(Prairie Princess ³ x Morden Amorette ⁴) x {Morden Cardinette ⁵ x [<i>R. rugosa alba</i> x (<i>R. arkansana</i> x Assiniboine ⁶)]}
Morden Blush	(Prairie Princess x Morden Amorette) x {Prairie Princess x [White Bouquet ⁷ x (<i>R. arkansana</i> x Assiniboine)]}
Morden Centennial	Prairie Princess x [White Bouquet x (<i>R. arkansana</i> x Assiniboine)]
Prairie Joy	Prairie Princess x Morden Cardinette
Winnipeg Parks	(Prairie Princess x Cuthbert Grant ¹) x (Lammerts #76001 x Morden Cardinette)
N3	Lilli Marleen ⁸ x seedling (mixed polycross seedling selection)
T5	(Prairie Princess x Cuthbert Grant) x Prairie Princess
X6	(Prairie Princess x Morden Amorette) x [Mount Shasta ⁹ x (Adelaide Hoodless ¹⁰ x <i>R. arkansana</i>)]
84SOJ401	[<i>R. kordesii</i> x (<i>R. rugosa alba</i> x #70-0225)] x {Morden Cardinette x [Prairie Princess x (White Bouquet x (<i>R. arkansana</i> x Assiniboine))]} x [Adelaide Hoodless x (Independence ¹¹ x (<i>R. arkansana</i> x Donald Prior ¹²))]
91V8T201	Sunsprite ¹³ x {[Prairie Princess x (White Bouquet x (<i>R. arkansana</i> x Assiniboine))]} x [(Fire King ¹⁴ x (<i>R. arkansana</i> x Assiniboine)) x (<i>R. foetida</i> x (Adelaide Hoodless x (Fire King x (<i>R. arkansana</i> x Assiniboine))))] x [(White Bouquet x (<i>R. arkansana</i> x Assiniboine)) x Hazeldean ¹⁵)]

²Seedling x D.T. Poulsen.

³Carousel x (Morning Stars x Suzanne) (has *R. laxa* and *R. spinosissima*).

⁴{Prairie Princess x (White Bouquet x (*R. arkansana* x Assiniboine))} x {Adelaide Hoodless x [Independence x (Donald Prior x *R. arkansana*)]}.

⁵{Prairie Princess x [White Bouquet x (*R. arkansana* x Assiniboine)]} x {Adelaide Hoodless x [Independence x (*R. arkansana* x Donald Prior)]}.

⁶*R. arkansana* x Donald Prior.

⁷Glacier x Pinnocchio seedling (multiflora background).

⁸(Crimson Glory x *R. arkansana* x Donald Prior) x Assiniboine.

⁹(Our Princess x Rudolph Timm) x Ama.

¹⁰(No published parentage).

¹¹Fire King x (*R. arkansana* x Assiniboine).

¹²Baby Chateau x Crimson Glory (floribunda).

¹³Seedling x Spanish Sun.

¹⁴Moulin Rouge x Fashion.

¹⁵*R. spinosissima altaica* x Persian Yellow.

each plant had two to four new branches and seven to eight expanded green leaves per branch. Prior to each inoculation, percent germination of conidia on 2% water agar consistently exceeded 80%. Plants were inoculated with a spore suspension of 10^5 conidia per mL at a rate of 0.4 mL per plant using a DeVilbiss model 15 atomizer (DeVilbiss, Somerset, Pa.), allowed to dry for 30 min, placed in a polyethylene humidity chamber in darkness at 20 °C for 24 h, and subsequently returned to the growth room with a 14-h photoperiod at 20 °C. Humidity in the chamber was maintained at or near saturation by continuous operation of an ultrasonic humidifier. Air temperature and humidity in the chamber, monitored with a hygromograph (model 252; Lambrecht, Gottingen, Germany), were 20 ± 1 °C and 100% relative humidity (RH), respectively. Due to limited humidity chamber space, the roses were inoculated with one isolate at a time. In each experiment, four replicate pots per genotype were arranged in a randomized complete-block design in both growth room and humidity chamber. Four pots of 'Hope for Humanity', sprayed with distilled water plus the surfactant, were included with each experiment as controls against extraneous airborne inocula. The inoculum dose, temperature, and duration of leaf wetness required to permit infection and sporulation were deter-

mined in preliminary experiments (data not shown).

Components of partial resistance. Incubation period, lesion length, number of lesions, leaf area with symptoms, and sporulation capacity were the five components of partial resistance measured. Incubation period (IP) was recorded for each rose genotype as the period in days from inoculation to the first visible appearance of lesions. Lesion length [LL; the maximum length (mm) of lesions per genotype] was measured with vernier calipers. Number of lesions (NL) was counted visually on leaf disks (2.5 cm in diameter) punched out from the center of each of the inoculated leaflets with a cork borer. LL and NL were determined on 20 inoculated leaves per genotype, 14 d after inoculation. The leaves

were randomly selected from the four replicate plants per genotype and labelled prior to the inoculation.

Leaf area with symptoms (LAS; the percent leaf area covered by black spot lesions) was estimated visually and the observations were classified in eight categories of a scale modified from Horsfall and Cowling (1978). The eight categories were 0% [median value (m.v.) = 0%], <1% (m.v. = 0.5%), 1% to 5% (m.v. = 2.5%), 6% to 10% (m.v. = 7.5%), 11% to 25% (m.v. = 17.5%), 26% to 50% (m.v. = 37.5%), 51% to 75% (m.v. = 62.5%), and >75% (m.v. = 87.5%). The mean LAS values of leaves of an individual plant were calculated using the equation $LAS = (m.v. \times \text{no. leaves in category}) / \text{total no. leaves}$. LAS was determined three times, 6, 10, and 14 d after inoculation.

Sporulation capacity (SC; the number of conidia produced per mm² of lesion) was assessed 17 d after inoculation. To measure SC, plants at 14 d after inoculation were placed in 100% RH at 20 °C for 48 h. Ten leaflets, selected at random from each of the four replicate plants per genotype, were cut into small pieces (≈ 1 cm²) and put into 10 mL of distilled water contained in a 1.8-cm-diameter glass tube. The tube was shaken for 1 min on a Vortex Genie 2 shaker (Fisher Scientific, Nepean, Ont., Canada) to dislodge conidia. The suspension was passed through two layers of cheesecloth to remove leaf and mycelial fragments. The concentration of spores in suspension was determined with a haemocytometer. SC was calculated as the number of conidia per unit lesion area for each inoculated plant using the formula: $SC = \text{no. spores} / \text{total leaf area for the 10 leaflets} \times \% \text{ LAS}$.

Data analysis. Since the testing of the two isolates was conducted under controlled and standardized environmental conditions, data were analyzed using a two-factor factorial design and treatment means were separated by least significant difference (LSD) test at $P = 0.05$. Correlation coefficients among resistance components were determined by Pearson correlation analysis. Analyses were performed using the Statistic Analysis System for personal computers (Cody and Smith, 1991).

Results

Analyses of variance indicated that, overall, cultivar had a highly significant ($P < 0.01$) effect on all five partial resistance components measured (Table 2). Isolate had a significant effect on SC but not on other components.

Table 2. Mean squares from analysis of variance for effects due to isolate, cultivar, and their interactions on percent leaf area with symptoms (LAS), incubation period (IP), number of lesions (NL), lesion length (LL), and sporulation capacity (SC).

Source of variance	Degrees of freedom	LAS			IP	NL	LL	SC
		Day 6	Day 10	Day 14				
Replication	3	1.6	10.3	22.2	2.2	1.4	290.3	1.7
Isolate	1	4.1	22.7	379.2	6.7	45.7	0.1	28.6*
Cultivar	10	9.6**	449.4**	1742.0**	32.5**	95.9**	2129.6**	34.2**
Isolate x cultivar	10	1.8	122.4**	272.8*	4.4	54.3**	797.4*	6.4
Error	44	1.0	33.2	100.9	2.1	14.9	316.9	4.5

* **Significant at $P < 0.05$ and 0.01 , respectively.

Table 3. Differences in components of partial resistance of 11 garden rose cultivars and lines to two isolates of *Diplocarpon rosae* in controlled conditions.

Isolate	Cultivar/line	Resistance component ^a						
		% LAS			IP	NL	LL	SC
		Day 6	Day 10	Day 14				
MO952	84SOJ401	3.0 b ^y	12.5 b	24.2 bc	4.7 c	2.4 ab	12.4 a	4.9 b
	91V8T201	0.0 e	0.0 d	0.0 e	---	---	---	---
	Cuthbert Grant	0.0 e	2.9 cd	5.7 de	8.7 a	0.5 d	3.5 d	57.7 a
	Morden Blush	0.0 e	10.4 bc	30.5 b	7.7 a	0.7 c	5.1 cd	14.9 b
	Morden Centennial	4.9 a	11.7 b	16.8 b-d	4.3 c	2.0 ab	9.2 b	5.2 b
	N3	0.7 c-e	5.0 b-d	10.4 c-e	7.7 a	0.7 c	7.2 bc	5.8 b
	Prairie Joy	2.4 bc	7.4 b-d	9.6 c-e	5.3 bc	3.2 a	5.7 cd	0.1 b
	T5	1.8 b-d	5.0 b-d	8.9 c-e	5.3 bc	0.5 c	3.3 d	7.8 b
	Hope for Humanity	1.9 b-d	38.3 a	68.7 a	5.7 bc	2.8 ab	9.2 b	28.1 b
	Winnipeg Parks	0.3 de	8.9 bc	24.1 bc	7.0 ab	0.8 cd	5.2 cd	8.9 b
	X6	1.0 c-e	2.5 cd	2.9 de	7.0 ab	0.7 cd	5.2 cd	0.0 b
		1.0 bc	9.0 cd	27.6 bc	6.7 bc	1.1 bc	7.7 bc	8.6 dc
OT953	84SOJ401	0.0 c	0.0 d	0.0 f	---	---	---	---
	91V8T201	1.3 bc	10.4 b-d	29.0 bc	6.3 bc	1.7 b	7.6 bc	68.2 ab
	Cuthbert Grant	0.0 c	9.6 cd	19.7 c-e	8.0 ab	1.0 bc	10.3 ab	44.5 bc
	Morden Blush	4.1 a	31.1 a	45.2 ab	4.3 c	3.5 a	10.2 ab	11.6 cd
	Morden Centennial	0.0 c	6.4 cd	24.0 cd	7.7 ab	0.7 bc	7.3 bc	19.9 cd
	N3	1.0 bc	4.1 d	7.0 d-f	6.7 bc	0.7 bc	9.4 a-c	12.9 cd
	Prairie Joy	0.2 bc	3.5 d	7.7 d-f	8.7 ab	0.3 c	3.8 c	1.6 d
	T5	0.7 bc	21.1 ab	53.1 a	6.3 bc	0.8 bc	8.9 a-c	99.0 a
	Hope for Humanity	1.6 b	17.3 bc	36.7 a-c	5.7 bc	0.9 bc	14.1 a	14.8 cd
	Winnipeg Parks	0.7 bc	4.9 d	4.7 ef	10.0 a	0.1 c	3.5 c	0.0 d
	X6							

^a% LAS (percent leaf area with symptoms) was estimated three times at 6, 10, and 14 d after inoculation, respectively. IP (incubation period) = time (day) from inoculation to the appearance of lesion; NL (number of lesions) = number of lesions per cm² of leaf at 14 d after inoculation; LL (lesion length) = maximum length of lesion at 14 d after inoculation; SC (sporulation capacity) = number of conidia per mm² of lesion at 17 d after inoculation (including 2 d in the dew chamber to induce sporulation).

^bMean separation within isolates and columns by LSD at $P \leq 0.05$.

^cNo symptoms were observed at 14 d after inoculation.

Interaction was significant ($P < 0.05$ or 0.01) for LAS at 10 and 14 d, but not at 6 d after inoculation, and significant ($P < 0.05$) for LL, but not for IP and SC.

No visible symptoms were observed on line 91V8T201 even at 14 d after inoculation; thus, the line was considered completely resistant to both isolates (Table 3). Black spot developed on the remaining 10 rose genotypes, but differed in various components measured. These genotypes were considered partially resistant.

Within the 10 rose genotypes exhibiting partial resistance, LAS varied between 0.0 and 4.9, 2.5 and 38.3, and 2.9 and 68.7 for isolate MO952, and between 0.0 and 4.1, 2.5 and 31.1, and 4.7 and 53.1 for isolate OT953 when observed at 6, 10, and 14 d after inoculation, respectively. Although significant genotypic differences in LAS were found for all three observation times, LAS at 10 or 14 d after inoculation gave greater ranges in response. On highly susceptible genotypes, lesions often coalesced and severely infected leaves began to abscise 18 d after inoculation. Genotypes X6, T5, and 'Prairie Joy' had a relatively low level of LAS (<10%), while 'Hope for Humanity' had significantly higher LAS (>53%) to both isolates than all other genotypes tested. 'Cuthbert Grant' had a low LAS (5.7%) to isolate MO952, but was intermediate (29.0%) to isolate OT953. The remaining six rose genotypes had intermediate levels of LAS.

IP varied between 4.3 d for 'Morden Centennial' to both isolates used and 10.0 d for X6 to isolate OT953. Other genotypes were intermediate, with IP ranging from 5.7 to 7.9 d when averaged over the two isolates.

The number of lesions per cm² leaf surface

(NL) varied between 0.5 for 'Cuthbert Grant' and T5 and 3.2 for 'Prairie Joy' to isolate MO952, and between 0.1 for X6 and 3.5 for 'Morden Centennial' to isolate OT953. Lines T5, X6, and N3, with NL ≤ 0.7 lesion per cm², were considered resistant. An isolate-specific interaction was observed for three genotypes out of the 11 tested. 'Cuthbert Grant' was resistant to isolate MO952, but had intermediate reaction (1.7 lesions per cm²) to isolate OT953. 'Hope for Humanity' and 'Prairie Joy' were resistant to isolate OT953, but susceptible (2.8 and 3.2 lesions per cm², respectively) to isolate MO952.

LL varied between 3.3 and 12.4 mm for T5 and 84SOJ401, respectively, to isolate MO952, and between 3.5 and 14.1 mm for X6 and 'Winnipeg Parks', respectively, to isolate OT953. Lines T5 and X6 had the shortest LL (≤ 5.2 mm) to both isolates and were considered resistant. 'Morden Blush' and 'Winnipeg Parks' were resistant to MO952, but developed the greatest LL (>10 mm) when challenged with OT953.

SC varied from no sporulation detected on line X6 to both isolates to 99 spores per mm² lesion on 'Hope for Humanity' to isolate

OT953. Averaging the two isolates gave, in descending order of SC for the 10 rose genotypes, X6, T5, 84SOJ401, 'Prairie Joy', 'Morden Centennial', 'Winnipeg Parks', N3, 'Morden Blush', 'Cuthbert Grant', and 'Hope for Humanity'.

All paired correlations among LAS, IP, NL, and LL were highly significant ($P < 0.01$) (Table 4). However, correlations of SC with these components were nonsignificant, with the exception of SC with LAS at 10 or 14 d after inoculation. Correlation coefficients of SC with LAS were relatively low ($r = 0.26$ and 0.33 , respectively) for 10 and 14 d.

Discussion

The 11 rose genotypes tested in this study represent the range of resistance to black spot that is currently available in the Morden rose breeding program. Our results indicate that various genotypes may have different mechanisms of resistance to the pathogen. The breeding line 91V8T201 exhibited complete resistance, while partial resistance was demonstrated in the 10 remaining rose genotypes. Resistance differences among these genotypes

Table 4. Correlation coefficients relating percent leaf area with symptoms (LAS), incubation period (IP), number of lesions (NL), lesion length (LL), and sporulation capacity (SC).

	LAS		IP	NL	LL
	Day 10	Day 14			
LAS (day 14)	0.89**				
IP	-0.54**	-0.51**			
NL	0.65**	0.53**	-0.61**		
LL	0.51**	0.51**	-0.64**	0.46**	
SC	0.26*	0.33*	-0.13	0.06	0.22

*,**Significant at $P < 0.05$ or 0.01 , respectively (66 degrees of freedom).

for the various components may be controlled polygenically and such resistance is believed to be durable (Parlevliet, 1993; Shaik, 1985). Although the two isolates used were collected from areas with different geographic and environmental characteristics, we cannot guarantee that they represent the entire Canadian *D. rosae* population. Svejda and Bolton (1980) suggested that *D. rosae* isolates can be rather diverse in pathogenicity. In the present study, genotype-isolate interactions were observed in three of the five components measured (Table 2). However, the mean square values for this source of variation were low compared to those of genotypes and not enough to differentiate pathotypes between the two isolates.

This study also indicated a wide range of differences in the five components of partial resistance to black spot among rose genotypes. Line X6 was identified as possessing the highest degree of partial resistance expressed as long IP, low LAS, low NL, short LL, and low SC. Line T5 was ranked second, closely followed by 'Prairie Joy'. 'Prairie Joy' had somewhat greater NL to isolate MO952, but was otherwise similar to T5. Conversely, 'Hope for Humanity', 'Winnipeg Parks', 'Morden Centennial', and 84SOJ401 showed short IP, high LAS, high NL, long LL, and high SC. These four genotypes exhibited the lowest degree of partial resistance. These results were consistent with observations of black spot resistance in these cultivars in field conditions (C.G. Davidson, unpublished). The differences in these components have not been previously reported in rose genotypes.

Our data indicate that a number of sources of resistance to black spot are available in garden roses, and these should be suitable for use in breeding programs in the colder regions of Canada. However, due to the highly variable nature of *D. rosae* reported in Canada (Svejda and Bolton, 1980), a preference should be given to the use of germplasm with a high level of partial resistance. The complete resistance exhibited by line 91V8T201 is probably controlled by a specific gene(s), and may be overcome when the appropriate virulence gene(s) are selected in the pathogen populations. In a separate study, black spot symptoms were observed on line 91V8T201 under field conditions in late August (C.G. Davidson, unpublished). However, the appearance of black spot on 91V8T201 may have been due (at least in part) to the physiological changes in the plant, since the disease is generally more

severe and progresses much faster on older foliage than on vigorously growing leaves in spring and summer. The incidence of black spot observed on this plant may have been due to the changes in the pathogen virulence. The durability of resistance of this line is becoming questionable. Unlike annual crops, roses are long-lived perennials and remain in the landscape for many years. Plants are repeatedly challenged by new and potentially more virulent strains. Genotypes with high levels of partial resistance, such as X6, T5, and 'Prairie Joy', may be more desirable as sources of resistance for rose breeding programs dealing with *D. rosae* populations in Canada.

Correlations among components of LAS, IP, NL, and LL were not considered high (maximum *r* value was 0.65, obtained between NL and LAS at 10 d after inoculation). Correlations of SC with these components were even lower (0.33 being the highest *r* value; Table 4). These results suggest that any one component may not suffice to explain the partial resistance potential of a particular genotype. The determination of partial resistance for a large number of rose genotypes, if all components were measured, would be laborious. To minimize the labor requirement when evaluating a large number of rose genotypes in the greenhouse, assessments of LAS and SC appear to be more important and preferable. Since LAS, IP, NL, and LL were significantly correlated, they may not all be required for large-scale greenhouse seedling screening trials.

Breeding for partial resistance to black spot at Morden is still in the developmental stage. *Rosa arkansana* has been used as a primary source of hardiness in the development of the "Parkland" roses in the Morden rose breeding program. This is a native plant, but it lacks resistance to black spot disease (Collicutt, 1992; Davidson, unpublished). However, the integration of black spot resistance and winter hardiness appears to be possible and achievable from hybrids among a wide range of rose germplasm (Table 1). The use of genotypes with high levels of partial resistance in a breeding program will enable the pyramiding of genes in subsequent generations to give durable resistance. Further studies are needed on correlations between component responses and disease progress in the field, and on host-pathogen relationships by exposing these partially resistant genotypes to many different *D. rosae* isolates.

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