Host Resistance in *Pyrus* to *Fabraea* Leaf Spot

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Abstract. Pear leaf spot, caused by the fungus *Fabraea maculata* Atk. (anamorph: *Entomosporium mespili* (DC.) Sacc.) occurs in most areas of the world where pears are grown. Most major cultivars of the European pear, *P. communis* L., for which data are available are susceptible. Ratings appearing in the literature are sometimes contradictory. This study evaluated resistance/susceptibility within a diverse collection of *Pyrus* cultivars and other germplasm in a randomized and replicated nursery plot using quantitative measures of disease incidence and severity. The least susceptible genotypes were the *P. communis* cultivars ‘Beurre Fouquieray’ and ‘Bartlett’, the *P. pyrifolia* cultivars ‘Imamura Aki’, and the *P. communis* × *P. ussuriensis* hybrid NJ 477643275.

Pear leaf spot, caused by the fungus *Fabraea maculata* Atk. (anamorph: *Entomosporium mespili* (DC.) Sacc.) occurs in most areas of the world where pears are grown under warm, humid conditions. Susceptible cultivars are often defoliated by midsummer resulting in weak trees and a reduction in fruit buds. Infected fruits are disfigured, cracked, misshapen, and unmarketable as fresh fruit. In the nursery the disease can be serious, causing defoliation and stunted growth (Anderson, 1956). Most major cultivars of the European pear, *P. communis* L., for which data are available are considered susceptible (Bell, 1991). However, ratings appearing in the literature are sometimes contradictory. Resistance to *Fabraea* leaf spot has been reported in some cultivars of *P. communis*, notably ‘Clapp Favorite’, ‘Doyenné du Comice’, ‘Minister Dr. Lucius’, ‘Louise Bonne d’Avranches’ and ‘Duchesse d’Angoulême’ (Esmarch, 1935; Koch, 1907). However, while Kovalev (1963) listed ‘Beurre Diel’ and ‘Bartlett’ as resistant, Esmarch (1935) reported them to be susceptible.

Genotypes of a number of East Asian species, *P. ussuriensis* Maxim., *P. pyrifolia* (Burm.) Nak., *P. calleryana* Decne., *P. fauriei* Scheid., and *P. dimorphophylla* Mak., have been reported as resistant (Beck, 1958; Kovalev, 1940; Tukey and Braese, 1934; and Wisker, 1916). Zaleski et al. (1959) reported that seedlings of *P. caucasia* Fed. were more resistant than interspecific hybrids of *P. salicifolia* Pall. or *P. amygdaliformis* Vill. with *P. communis*. A multi-year study of 207 *Pyrus* genotypes (Bell and van der Zwet, 1988) demonstrated variability within and among species and interspecific

hybrids. Pure species or interspecific hybrids involving *P. calleryana*, *P. pyrifolia* and *P. ussuriensis* were generally more resistant than *P. communis* genotypes. Drain (1954) noted resistance in the *P. communis* × *P. pyrifolia* hybrids, ‘Mooers’ and ‘Hoskins’. Lombard and Westwood (1987) listed seedlings of *P. caucasia* and *P. cordata* Desv. as moderately tolerant, those of the Circum-Mediterranean species *P. amygdaliformis*, *P. elaeagnifolia* Pall., and *P. syriaca* Boiss., and seedlings and clones of *P. betulifolia* Bunge as having high tolerance, *P. calleryana* seedlings and clones as very tolerant, and *P. pashia* D. Don. as susceptible. In contrast to some of the other studies, Lombard and Westwood (1987) list *P. pyrifolia* and *P. ussuriensis* as having only low tolerance.

One explanation of the disparity among these studies is that each species is heterogeneous for this trait. Furthermore, all studies thus far reported are based upon epiphytotic infections in nonrandomized orchard plots and have not been corroborated by controlled studies. Studies based upon artificial inoculation were not possible due to the lack of an *in vitro* cultural medium suitable for the production of large amounts of inoculum until improvements developed by van der Zwet and Stroo (1985). In addition, the ratings were based upon relatively undefined subjective scales, with the exception of a previous study by Bell and van der Zwet (1988), which used a scale based on a visual estimate of the number of lesions and degree of defoliation.

Effective control of the disease requires frequent applications of fungicides throughout the growing season, especially after periods of rain. Cultivars with resistance would reduce grower costs and potential residues associated with pesticide usage. Reliable evaluation methods are needed, and the use of small nursery plots may be more efficient in terms of space and maintenance requirements than orchard plots. This study sought to evaluate resistance or susceptibility within a diverse collection of *Pyrus* cultivars and other germplasm in a

randomized and replicated nursery plot using quantitative measures of disease incidence and severity.

Materials and Methods

Plant material. Thirty-four genotypes of pear (Table 1) were selected to represent a range of susceptibility and genetic diversity, and with the exception of three additions, were selected from genotypes studied previously (Bell and van der Zwet, 1988). Five rows of ‘Bartlett’ seedling rootstocks were planted in a nursery block at a spacing of about 1.5 m between rows and 0.6 m between trees. Two trees of each genotype were produced by budding in late summer in a random order onto two rootstocks in each row, and grown into single leader trees the following spring. Lack of bud take reduced the number of trees produced for some genotypes, leading to incomplete blocks (i.e., rows). However, at least three trees of each genotype, and as many as eight, were used in the study. No fungicides were applied during the study. Jones and Aldwinckle (1990) stated that the primary inoculum consists of ascospores and conidia from overwintering leaves, as well as conidia from twig cankers. Therefore, leaves from infected trees in the orchard were collected during the previous fall and spread uniformly in the nursery in an attempt to provide natural inoculum.

Disease evaluation. During the summer, random leaves were examined to confirm that the symptoms were consistent with *Fabraea maculata*. In late August, 10 leaves were collected from the apical through the basal portions of each tree. The number of lesions per leaf were counted and the most prominent lesion size was estimated using a numeric scale (0 = no lesions; 1 = pinpoint to small; 2 = medium, about 2 to 3 mm in diameter; 3 = large, greater than about 3 mm in diameter; 4 = coalescing necrotic lesions). Relatively little defoliation was observed in the nursery, and therefore, in contrast to the scoring system utilized previously by Bell and van der Zwet (1988), no data on severity of defoliation were collected. In a few cases, some leaves on a tree had been lost due to defoliation or insect damage and the number of leaves per tree on which data could be collected was reduced. Leaf area was measured using a leaf area meter (LI-COR Biosciences, Lincoln, Neb.), and the number of lesions per square centimeter leaf area was calculated.

Statistical analysis. The linear model was a nested linear model with genotypes treated as fixed effects and trees within genotypes and leaves within trees as random effects. The data were analyzed as a completely randomized design due to the incomplete nature of the blocks (i.e., rows). The residuals were computed using SAS PROC MIXED (Littell et al., 1996) and analyzed for normality using the Shapiro-Wilk test and normal probability plots using SAS PROC UNIVARIATE (SAS Institute, 1990). The distribution of mean number of lesions per tree ($W = 0.81$, $P < W = <0.0001$) was not normal, probably due primarily to kurtosis. The distribution of mean lesions per leaf area

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per tree ($W = 0.59$, $P < W = <0.0001$) were not normal, also due to kurtosis, but the mean lesion size per tree was normally distributed ($W = 0.99$, $P < W = 0.53$). Variances of number of lesions per leaf per genotype were found to be unequal according to plots of residuals versus genotype means and Bartlett's homogeneity of variance test option in SAS PROC GLM (SAS Institute, 1990) (chi-square = 169.5, $P >$ chi-square = <0.0001). In addition, Spearman's rank correlation, computed using SAS PROC CORR (SAS Institute, 1990), between residuals and genotype means was highly significant ($r = 0.67$, $P < 0.0001$). Variance of the residuals for number of lesions per leaf area were not equal according to the residual versus mean plots, Spearman's rank correlation ($r = 0.65$, $P < 0.0001$), and Bartlett's test (chi-square = 166.7, $P >$ chi-square = <0.0001). Variance of lesion size residuals were equal according to Bartlett's test (chi-square = 32.0, $P >$ chi-square = <0.41), although the residual versus mean plot was inconclusive, due to the discrete nature of the scores. Data for number of lesions per leaf and lesions per leaf area were log transformed. Analysis indicated improvement in equality of variances and normality.

Analyses of variance was performed using SAS PROC MIXED, with denominator degrees of freedom computed by Satterthwaite's method and differences in least-square means adjusted and tested using the Tukey option (Littell et al., 1996). Pearson's correlation coefficients were computed between genotypic means for number of lesions per leaf, lesion size, and lesions per leaf area. Rank correlations between these variables and the mean and minimum severity scores reported in Bell and van der Zwet (1988) were computed. Rank correlations were computed between the proportion of infected leaves and mean lesion size.

Results and Discussion

Differences among genotypes were highly significant ($P > F = 0.003$ to 0.0001) for number of lesions, leaf area, number of lesions per unit leaf area, and lesion size. Variance due to differences among individual trees of each genotype was also highly significant ($P > F = 0.0001$) for each measured variable, indicating the need for adequate replication and randomization. Use of infected leaves distributed in the nursery was apparently not effective in achieving uniform inoculum levels throughout the nursery plot. The frequencies of infected leaves on grafted trees were generally high, indicating a lack of immunity. All leaves of fifteen genotypes had at least one lesion on each leaf, but as many as seven leaves of 'Lincoln' had no lesions, either through escape or resistance. There was no relationship between presence or number of uninfected leaves and other measures of infection. Most noninfected leaves for a genotype were on the same tree (data not shown).

The least susceptible genotypes were the *P. communis* cultivars 'Beurre Fouquieray' and 'Bartlett', the *P. pyrifolia* cultivar 'Imamura Aki', and the *P. ussuriensis* × *P. pyrifolia* hybrid NJ 477643275 (Table 1). The most susceptible

genotype, with >12 lesions/cm² of leaf area, was NY 10353. This genotype developed almost twice the number of lesions per leaf area as the next two most susceptible genotypes, NY 10354 and NY 10355. All three of these are *P. communis* × *P. ussuriensis* BC₁ interspecific hybrids. Severe early season defoliation of NY 10353 has been observed in our unsprayed orchard block.

Mean lesion size was smallest in Illinois 76, putatively an interspecific hybrid of *P. ussuriensis* and *P. pyrifolia* (L. F. Hough, pers. comm.), and NJ 477643275, a seedling of Illinois 76 and 'Pai Li'. Mean lesion size ranged continuously up to 'Pai Li' and 'Pontotoc'. Five of the six genotypes with the lowest numbers of lesions per unit leaf area also had the smallest mean lesion size ratings, suggesting that the mechanism of resistance that affects incidence of infection may also retard lesion development.

There were moderate to high positive correlations between mean number of lesions and lesion size ($r = 0.54$, $p = 0.001$) and with lesions per leaf area ($r = 0.79$, $p = <0.0001$). There was a moderately small, positive rank correlation ($r = 0.37$, $p = 0.03$) between the mean proportion of infected leaves and mean lesion size. These observations suggest that

factors affecting whether infection occurs are at least moderately associated with those affecting severity of infection.

Due to significant variability among trees of a single genotype, which resulted in many overlapping classes in the mean separation test, the replicated nursery screening technique was only moderately useful for identifying the most resistant and the most susceptible genotypes, at least in a single-year study. The rank correlation between the mean number of lesions per leaf area and the mean scores reported in Bell and van der Zwet (1988) was low and not significant ($r = -0.28$, $p = 0.12$), while the rank correlation with the minimum scores was moderate and significant ($r = -0.38$, $p = 0.03$). One reason for the low correlations may be the relative importance of leaf lesions as a source of inoculum. While conidia which overwintered on infected leaves can serve as a source of inoculum during the spring, overwintering bark cankers are a more important source in mature trees trained and pruned according to standard commercial practice (Goldsworthy and Smith, 1938). In such trees, the lowest leaves would be further from the overwintered leaf litter than the leaves of young single-shoot trees used in our current study. Horie and Kobayashi (1980) concluded that conidia from

Table 1. Mean per genotype for number of lesions, lesion size, leaf area, and number of lesions per unit leaf area.

Genotype	Species ^a	No. leaves	No. lesions per leaf	Lesion size ^b	No. lesions/cm ² leaf area ^c
NJ 477643275	UP	10	4.7 a ^w	1.4 a	0.2 a
Imamura Aki	P	45	12.2 a	1.6 ab	0.5 a
Bartlett	C	30	7.6 a	1.6 ab	0.7 a
Beurre Fouquieray	C	36	9.5 a	2.1 a-e	0.7 a
Illinois 76	UP	28	10.9 a	1.3 a	0.8 ab
Maxine	C	37	10.9 a	1.6 abc	1.1 abc
Japan Golden Russet	P	10	16.2 a	2.0 a-e	1.2 abc
Roi Charles de Wurtemberg	C	29	13.4 a	2.6 b-e	1.3 abc
Meigetsu	P	50	37.1 ab	2.4 a-e	1.6 abc
Lincoln	C	63	12.2 a	1.8 a-e	1.8 a-d
NY 10274	C	60	22.7 a	1.9 a-e	1.9 a-d
Illinois 5E-18	PC	29	23.8 a	2.4 a-e	1.9 a-d
Moonglow	C	67	21.9 a	2.6 b-e	2.0 a-d
Ames	PC	60	23.4 a	1.9 a-e	2.1 a-d
Ba Li Hsiang	U	40	39.2 ab	2.3 a-e	2.1 a-d
Krylov	UC	60	19.3 a	2.4 a-e	2.1 a-d
Beierschmidt	C	18	19.5 a	2.1 a-e	2.2 a-d
NY 10369	C	50	24.0 a	2.0 a-e	2.3 a-d
O-46-77	UC	59	19.3 a	2.3 a-e	2.3 a-d
China	P	20	39.2 ab	2.4 a-e	2.3 a-d
Monterrey	PC	69	44.3 abc	2.0 a-e	2.3 a-d
NJ A2 R29 T83	UPC	65	15.1 a	1.7 a-e	2.6 a-d
Indiana TH 1-187	UPC	40	41.3 ab	2.0 a-e	2.6 a-d
Huang Hsiang Sui Li	U	60	56.0 a-d	2.8 de	2.7 a-d
NY 10359	UC	48	37.8 ab	2.2 a-e	2.8 a-d
Pontotoc	PC	31	62.5 a-d	2.9 e	3.6 a-d
Tenn 31S46	PC	38	41.1 abc	2.7 cde	3.7 a-d
Honeysweet	C	30	29.7 a	2.3 a-e	4.0 a-d
Tang Li	U	33	117.3 d	2.0 a-e	5.0 a-d
NJ 487603004	UPC	22	111.9 cd	2.3 a-e	5.4 bcd
Pai Li	U	30	106.0 bcd	3.0 e	5.7 cd
NY 10355	UC	27	63.5 a-d	2.3 a-e	6.3 d
NY 10354	UC	38	46.7 a-d	2.5 a-e	6.5 d
NY 10353	UC	25	108.2 bcd	2.8 de	12.6 e

^aSpecies: C = *P. communis*, P = *P. pyrifolia*, U = *P. ussuriensis*. Interspecific hybrids are indicated by appropriate combinations.

^bLesion size scale: 0 = no lesion; 1 = pinpoint to small; 2 = medium, about 2 to 3 mm in diameter; 3 = large, greater than about 3 mm in diameter; 4 = coalescing necrotic lesions.

^cLeaf area was measured in cm².

^wMean separation within columns by Waller-Duncan multiple range test (K ratio = 100). Means within each column followed by the same letters are not significantly different.

diseased overwintered leaves on the ground could serve as a source of primary inoculum on low growing plants, although shoot lesions would also be an important source of inoculum in taller plants, especially as secondary lesions developed during the growing season. The greater amount of inoculum to be expected on trees containing overwintering bark cankers may account for the generally more severe leaf spot infections observed in our earlier study of mature trees (Bell and van der Zwet, 1988). In that study data was collected later, in mid-September, and the more severe scores in that rating scale took into account percentage of defoliation. These differences in assessment date could also account for the generally more severe infection scores, and may have contributed to differences between the two studies. In spite of these differences, the use of objective measurements rather than subjective scales previously used should improve the usefulness and reliability of data. Collecting data in two or more consecutive years would also improve the utility of nursery screening, given the importance of young shoot and bark lesions as a source of inoculum.

As species groups, the *P. ussuriensis* × *P. pyrifolia* hybrids and the pure *P. pyrifolia* cultivars were most resistant, with mean numbers of lesions per leaf area of 0.5 and 1.4, respectively. These species and species hybrids were expected to be resistant, based upon our earlier study (Bell and van der Zwet, 1988). The level of disease observed for Illinois 76 also agrees with observations of Hough (1944), who selected this seedling from his study population. The pure *P. communis* cultivars and *P. pyrifolia* × *P. communis* hybrids averaged 1.8 and 2.7 lesions per unit leaf area, respectively. The means for the *P. ussuriensis* × *P. pyrifolia* × *P. communis* hybrids, *P. ussuriensis* × *P. communis*, and pure *P. ussuriensis* were 3.5, 3.9, and 5.4 lesions

per unit leaf area, respectively. The higher susceptibility observed in the present study, in contrast to previous cited studies, are probably due to differences in the genotypes studied. The most susceptible NY selections are derived from a single *P. ussuriensis* parent, Illinois 65, crossed with susceptible *P. communis* parents. Our present study did not include many of the cultivars previously reported to be resistant, but the *P. communis* cultivars 'Beurre Fougeray' and 'Bartlett', and to a lesser extent 'Maxine', 'Lincoln', and 'Moonglow', and the *P. pyrifolia* cultivars, 'Imamura Aki' and 'Japan Golden Russet', were moderately resistant in this study as well as in our previous study (Bell and van der Zwet, 1988). Our results for 'Bartlett' agree more closely with Kovalev (1963) than Esmarch (1935). 'Beurre Fougeray', 'Maxine', and 'Moonglow' combine moderate levels of resistance to *Fabreaea* leaf spot with resistance to fire blight. These cultivars should be particularly useful in breeding new disease resistant pear cultivars.

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