Evaluating Fire Blight Resistance among Flowering Crabapples (Malus spp.) and Pears (Pyrus spp.)

Andrew C. Bell[1], Thomas G. Ranney[1], Thomas A. Eaker[1], and Turner B. Sutton[2]

[1]Department of Horticultural Science, Mountain Horticultural Crops Research and Extension Center, North Carolina State University, 455 Research Drive, Mills River, NC 28759
[2]Department of Plant Pathology, North Carolina State University, 1320 Varsity Drive, Raleigh, NC 27695-7643

Introduction

Fire blight, caused by the bacterium Erwinia amylovora, is one of the most significant diseases of rosaceous plants, particularly those members in the subfamily Maloideae. Susceptible plants, including taxa of flowering pears and crabapples, can be severely damaged and killed by fire blight in both nursery and landscape plantings. This disease can be especially problematic in both the eastern and mid-western regions of the United States where environmental conditions are favorable for the pathogen. Although many taxa are susceptible to fire blight, flowering pears and crabapples vary considerably in resistance to this disease providing opportunities for the selection and development of superior plants (Benson et al.,1991; Windham et al., 1997)

Research on fire blight resistance among flowering pears and crabapples has been limited and has primarily been based on observations of natural infection (Benson et al., 1991; Green, 1986; Nichols, 1983, 1986; Windham et al., 1997). Because the incidence of fire blight can be sporadic and vary from region-to-region and year-to-year, observations and results from field surveys can be inconsistent and highly variable. Plants that initially appear to be resistant may later be found to be susceptible when conditions are favorable for pathogen development. Controlled inoculations of actively growing shoots with E. amylovora can provide an effective and consistent means for evaluating fire blight resistance (Aldwinckle and Preczewski, 1979; Bonn and Elfving, 1990).

Materials and Methods

Crabapples

Forty-nine Malus taxa, in a field plot arranged as a randomized complete block experimental design with three replications, were screened for fire blight resistance at the Mountain Horticultural Crops Research Station, Mills River (formerly Fletcher), NC. Trees were planted between March 1990 and March 1991.

Controlled Inoculations. On 20 May 1999, four random shoots (subsamples) on each tree were inoculated with Erwinia amylovora strain Ea 273 at a concentration of ~ 4.7 x 10^8 cfu / ml. Inoculations were conducted by bisecting the two youngest leaves, on actively growing shoots, with scissors that had been dipped into the inoculum prior to each cut (Figs.1 and 2). Disease assessments were made 40 days after the initial inoculations. Lesion length and total length of the current season's growth were measured. The severity of infection was calculated as the length of the fire blight lesion as a percentage of overall shoot length. Additional inoculations were conducted on 11 May 2000 using the same technique and field plot described above. However, at this time, three separate strains of Erwinia amylovora (273, 2002A, and 4001A) were applied to each tree. There were four replicates (subsamples) of each strain on each tree with a split-plot treatment design.

Natural Infection. Trees in the same field plot as described above were also evaluated for natural occurrence of fire blight.Disease severity was rated during the summers of 1994, 1995, and 1999 (see Table 2 for rating scale).

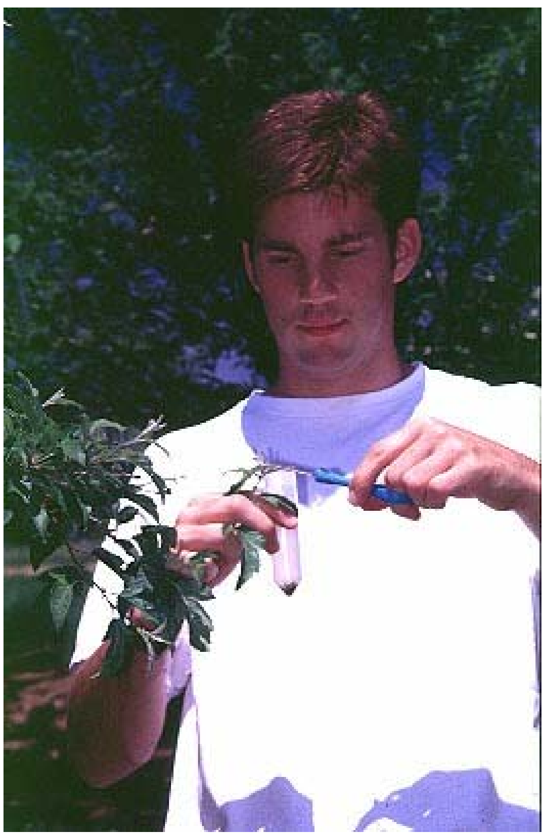

Figure 1. Andrew Bell innoculating Malus

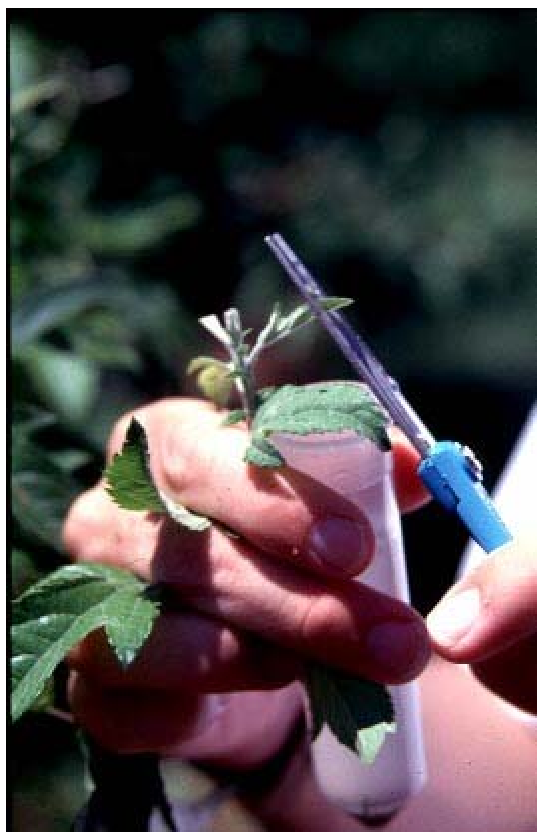

Figure 2. Innoculation method

Pears

Twenty-seven taxa of containerized Pyrus, arranged in a randomized complete block experimental design with 4-12 replications, were screened for fire blight resistance. One to two actively growing shoots (subsamples) per tree were inoculated as previously described. Erwinia amylovora strain 2002A served as the inoculum at a concentration of ~$1.53 x 10^7$ cells / ml. Data collection was conducted as described above. All data was subject to analysis of variance.

Inoculum. Strains of Erwinia amylovora were provided by Drs. Herb Aldwinckle and John Norelli at Cornell University. All three strains used had been previously categorized and known to be virulent on both Pyrus and Malus taxa.The bacteria were stored in 25% glycerol in a 80 C freezer. Cultures were grown on nutrient agar at 25 C for 3 days prior to the inoculations. The bacterial cultures were washed thoroughly with distilled water and loosened from the agar with a rubber-stirring tip. The bacterial suspension was collected and diluted with distilled water to a final volume of 500 ml.Dilution plating was used to determine the final concentration of the inoculum.

Results and Discussion

Crabapples

Controlled Inoculation. Ratings varied considerably among taxa and ranged from 0 to 100% of total shoot length (Table 1, Figs 3 and 4). In 1999, 'Sinai Fire', 'Schmidtcutleaf' and M. tschonoskii were highly susceptible and differed significantly from all other taxa screened. In the 2000 study, these same taxa were the most susceptible to all three strains. Lesions extended into prior year s growth on some of the replicates of 'Sinai Fire', 'Schmidtcutleaf', 'Silver Moon', and M. tschonoskii. Comparing the results of a single strain (273) over two years demonstrated the reliability of this technique. M. sieboldii 'Calocarpa' and David consistently received a low disease rating while M. tschonoskii, 'Sinai Fire', and 'Schmidtcutleaf' proved to be the most susceptible taxa in both years. In general, there appeared to be an increase in susceptibility in 2000 for most taxa. The cultivar 'David' is the only taxa that did not differ significantly from 0% infection, in both years including all three strains, thus suggesting that it is the most resistant taxa included here. 'Adirondack' and 'Adams' did not differ significantly from 0% infection with strains 2002A and 273 in both years but did differ significantly from 0% infection with strain 4001A.

Figure 3. Highly susceptible, Malus tschonskii.

Figure 4. Highly resistant, Malus sieboldii 'Calocarpa'

Disease ratings of natural infections varied considerably over the three years (Table 2). Nine, 14, and 22 taxa showed some infection for 1994, 1995, and 1999, respectively. Infection in 1999 was generally higher than in 1994 and 1995. There were many instances where certain cultivars had no disease in some years, but severe infections in others. For example, Malus tschonoskii and Malus 'Brandywine' received a zero rating for both 1994 and 1995 but had mean disease ratings of >2 for 1999.

In many cases there was considerable agreement between results from natural infection and controlled inoculations.The taxa M. sieboldii Calocarpa , David , and Adirondack showed no symptoms of natural infection in all three years, which was consistent with the high level of resistance observed under the controlled inoculations in 1999. 'Schmidtcutleaf', 'Sinai Fire', and M. tschonoskii all showed symptoms of natural infection, particularly in 1999 when all three received at least a rating of 2, also consistent with susceptibility found in controlled inoculations. However, there were also cases where plants appeared to be resistant based on natural infection, but were susceptible based on controlled inoculations.For example, 'Baskatong' and 'White Angel' showed no symptoms of natural infection for all three years, yet had mean lesion lengths ranging from 32 to 95% and 41 to 90% respectively depending on the year and the pathogen strain. Windham et al. (1997), reported 'White Angel' as "resistant" and 'Sinai Fire' as "moderately resistant" under natural disease pressure. In this study, 'White Angel' was found to be susceptible under controlled inoculations while 'Sinai Fire' was found to be one of the most susceptible cultivars under both natural and controlled conditions. Those cultivars reported as highly resistant in this study (i.e., 0% lesion length and rating = 0) have also been reported as being resistant by Windham et al. (1997).

Pears

The flowering pear taxa included in this study showed considerable variation in resistance to fire blight with infections ranging from 1 100 % of the current season s growth (Table 3, Figs. 5 and 6). Nine taxa were highly susceptible with extensive infection that did not differ significantly from 100%. The susceptible taxa included specific clones of P. fauriei*, P. elaeagrifolia, P. pyrifolia, P nivalis*, and P. salicifolia as well as a number of hybrid cultivars. At the other extreme, two taxa, Pyrus usseriensis Prairie Gem and Pyrus 950104 , a hybrid clone derived from open pollinated Pyrus callerya*n*a x Pyrus betulifolia, were highly resistant with minimal infection that was not significantly different from 0%. Fifteen other taxa were intermediate with lesions ranging from 16 to 81% of the annual shoot growth.

Figure 5. Highly susceptible, Pyrus spp.

Figure 6. Highly resistant, Pyrus '950104'

van der Zwet and Keil (1979) documented fire blight resistance for many economically important species of pears; Pyrus ussuriensis and P. calleryana were noted as being most resistant. It was reported, however, that seedling populations of all species screened showed considerable variation in levels of resistance. The study reported here included clonal selections of a number of species. The P. ussuriensis clone 'Prairie Gem' was extremely resistant.Comparisons among cultivars of P. calleryana showed significant differences with P.

calleryana 'Chanticleer' being more resistant than P. calleryana 'Fauriei', 'Bradford', 'Whitehouse', 'Aristocrat', and 'Red Spire'. Our results were in general agreement with Fare et al. (1991) and McNeil et al. (1986), who reported that the P. calleryana cultivars 'Bradford', 'Fauriei', and 'Whitehouse' showed greater resistant than 'Aristocrat' and 'Red Spire'; though in our study 'Whitehouse' was not significantly more resistant than either 'Aristocrat' or 'Red Spire'.We also found P. calleryana 'Chanticleer' (syn. 'Cleveland Select') to be significantly more resistant than 'Bradford'. Pyrus betulifolia 'Dancer', a clone of P. regelii, and the hybrid clone 93-70-2 (P. calleryana 'Chanticleer' x P. elaeagrifolia), were all as resistant or more resistant than P. calleryana 'Chanticleer'.

Conclusions

Variations in inoculum level, pathogen strain, and conditions favoring infection during bloom can all influence infection and disease caused by Erwinia amylovora. Our results indicate that field observations of fire blight susceptibility, under conditions of natural infection, can be misleading and may not be a reliable method for evaluating resistance. This research utilized a rigorous approach of controlled inoculations, with specific pathogen strains, to screen cultivars for resistance to fire blight under worst case conditions.Information from this study provides a more reliable basis for the selection and improvement of disease resistant flowering pears and crabapples. The results presented in this paper are being used as a foundation for additional research on the role of secondary plant metabolites in Malus, host plant resistance to E. amylovora, host by pathogen strain interactions,and the development of new disease resistant cultivars. Evaluation, selection, and improvement of cultivars with superior disease resistance will contribute to lower production costs, reduced need for pesticides, improved environmental quality, and superior products.

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Table 1. Fire blight ratings for controlled inoculations of flowering crabapples over two years.

Malus taxa	Strain: / Year:	273 1999	273 2000	2002A 2000	4001A 2000
sieboldii 'Calocarpa'		0[z]	1	24	28
'David'		0	1	1	6
'Adirondack'		0	2	9	36
'Sentinel'		1	4	86	79
'Adams'		1	1	12	16
'Pink Princess'		2	15	44	47
'Sutyzam' (Sugar Tyme™)		3	1	41	35
'White Cloud'		4	NA	NA	NA
'Centurion'		4	10	24	17
baccata 'Jackii'		4	14	46	56
'Radiant'		6	13	10	19
'Molten Lava'		6	19	53	56
'Pink Satin'		6	17	22	69
'Camzam' (Camelot™)		7	16	73	69
'Ormiston Roy'		7	4	47	56
'Prairifire'		7	43	93	79
'Indian Summer'		8	1	22	27
floribunda		9	16	18	46
'Robinson'		9	9	27	26
'Narragansett'		10	15	52	65
'Dolgo'		10	27	51	35
sargentii		10	48	83	59
'Liset'		11	10	76	78
'Jewelberry'		11	22	55	78
'Purple Prince'		11	52	91	98
'Strawberry Parfait'		11	21	48	74
'Callaway'		12	22	35	35
'Candy Mint'		13	60	85	86
'Glen Mills'		14	19	94	93
'Silver Drift'		14	0	79	100
'Snow Drift'		14	75	100	100
'Canary'		17	33	33	38
'Hargozam' (Harvest Gold™)		18	21	81	83
'Louisa'		19	10	23	27
'Prairie Maid'		22	91	100	88
'Red Splendor'		23	19	63	54
'Doubloons'		28	35	57	64
'Baskatong'		32	75	95	90
'Professor Sprenger'		33	12	38	85

‘Branzam’ (Brandywine™)	39	51	78	63
‘Mary Potter’	40	40	100	96
‘White Angel’	41	44	90	70
‘Mazam’ (Madonna™)	50	66	100	97
hupehensis	55	56	98	99
‘Donald Wyman’	61	60	93	97
‘Silver Moon’	61*	84*	99*	100*
‘Schmidtcutleaf’ (Golden Raindrops™)	91*	100*	100*	100*
tschonoskii	100*	100*	100*	100*
‘Sinai Fire’	100*	94*	100*	100*
LSD $_{0.05}$	26	18	24	15

[z] Controlled Inoculations: % of total shoot length infected.

* Lesion extended into prior years growth on some branches.

Table 2. Fire blight ratings for flowering crabapples based on natural infection.

Malus taxa	Natural Infection 1994	Natural Infection 1995	Natural Infection 1999
sieboldii 'Calocarpa'	0.0	0.0	0.0
'David'	0.0	0.0	0.0
'Adirondack'	0.0	0.0	0.0
'Sentinel'	0.3	0.7	0.0
'Adams'	0.0	0.0	0.0
'Pink Princess'	0.0	0.0	0.0
'Sutyzam' (Sugar Tyme™)	0.2	0.0	0.0
'White Cloud'	0.0	0.0	0.0
'Centurion'	0.0	0.0	1.0
baccata 'Jackii'	0.0	0.0	0.0
'Radiant'	0.0	0.0	0.7
'Molten Lava'	0.0	0.0	0.0
'Pink Satin'	0.0	0.0	0.0
'Camzam' (Camelot™)	NA	0.0	0.0
'Ormiston Roy'	0.0	0.7	1.7
'Prairifire'	0.0	0.0	0.0
'Indian Summer'	0.0	0.0	0.0
floribunda	0.3	1.0	1.0
'Robinson'	0.0	0.0	0.0
'Narragansett'	0.0	0.0	0.0
'Dolgo'	0.0	0.0	0.3
sargentii	0.0	0.0	0.0
'Liset'	0.0	0.0	0.7
'Jewelberry'	0.0	0.0	0.0
'Purple Prince'	0.0	0.0	0.0
'Strawberry Parfait'	0.3	0.0	0.0
'Callaway'	0.0	0.0	0.0
'Candy Mint'	0.0	0.0	0.0
'Glen Mills'	0.0	0.0	0.3
'Silver Drift'	0.0	0.0	0.7
'Snow Drift'	0.0	0.3	0.3
'Canary'	0.0	0.0	0.0
'Hargozam' (Harvest Gold™)	0.3	0.7	1.3
'Louisa'	0.0	0.0	0.2
'Prairie Maid'	0.0	0.0	0.0
'Red Splendor'	0.0	0.0	0.0
'Doubloons'	0.3	0.7	0.7
'Baskatong'	0.0	0.0	0.0
'Professor Sprenger'	0.0	0.3	0.3

‘Branzam’ (Brandywine™)	0.0	0.0	2.0
‘Mary Potter’	0.0	1.0	1.3
‘White Angel’	0.0	0.0	0.0
‘Mazam’ (Madonna™)	0.0	1.7	0.3
hupehensis	0.0	0.8	2.7
‘Donald Wyman’	0.0	0.3	0.5
‘Silver Moon’	1.3	2.0	2.7
‘Schmidtcutleaf’ (Golden Raindrops™)	1.0	2.0	2.3
tschonoskii	0.0	0.0	2.5
‘Sinai Fire’	1.0	0.7	2.0
$LSD_{0.05}$	0.5	0.4	0.8

Natural infection: 0=no evidence of fire blight, 1=few (1-3) branch tips infected, 2=numerous (>3) branch tips showing symptoms and few (1-3) major branches infected, 3=several (2-3) major branches infected and considerable dieback, 4=major (>30%) portion of the tree killed. NA = data not available.

Table 3. Fire blight ratings for controlled inoculations of flowering pears.

Pyrus taxa	% lesion length
950104[y] ( )	1 z
P. ussuriensis 'Prairie Gem'	3
P. betulifolia 'Dancer'	16
P. regelii	22
93-70-2[y] (*calleryana* 'Chanticleer' x *elaeagrifolia*)	22
P. calleryana 'Chanticleer'	31
93-61-1[y] (*amygdaliformis* x *calleryana* 'Chanticleer')	32
91-42-1[y] (*amygdaliformis* x *regelii*)	38
911014[y] ( )	42
93-15-1[y] (*elaeagrifolia* x *ussuriensis*)	44
P. calleryana 'Fauriei'	46
P. calleryana 'Bradford'	50
P. calleryana 'Whitehouse'	62
91-53-1[y] (*callyerana* 'Chanticleer' x *betulifolia*)	63
P. calleryana 'Aristocrat'	65
P. calleryana 'Red Spire'	69
93-17-3[y] (*elaeagrifolia* x *amygdaliformis*)	81
93-2-2[y] ((*calleryana* x *fauriei*) x *nivalis*)	87
P. fauriei 'Korean Sun'	89
P. elaeagrifolia 'Turkish Mist'	91
911010[y] ( )	92
93-32-4[y] (*salicifolia* 'Pendula' x *ussuriensis*)	94
P. pyrifolia	95
P. nivalis 808	97
93-8-5[y] (*fauriei* x *salicifolia* 'Pendula')	98
P. salicifolia 'Pendula'	100
$LSD_{0.05}$	15

[z] % of total shoot length infected
[y] interspecific hybrid taxa