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# VARIABILITY IN DEGREE OF FIRE BLIGHT RESISTANCE WITHIN AND BETWEEN *PYRUS* SPECIES, INTERSPECIFIC HYBRIDS, AND SEEDLING PROGENIES

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SUMMARY

One hundred seven selections from 17 species, 85 selections from controlled interspecific crosses, and a large number of species hybrids of pears were tested for resistance to fire blight (*Erwinia amylovora* (BURR.) WINSL. et al.). The degree of resistance varied between species and between the clones and selections within species. In species hybrids, resistance varied between selections. Because of this variability, a fixed resistance rating could not be assigned to any given species.

In interspecific crosses, resistance was not consistently transmitted either by crossing a highly resistant with a very susceptible species or by crossing two highly resistant species. The highest degree of overall resistance resulted from crossing two moderately resistant parents. Therefore, a given clone of a species should be tested for its individual degree of resistance before it can be used profitably in a breeding program.

## INTRODUCTION

Within the genus *Pyrus*, the degree and type of resistance to fire blight (*Erwinia amylovora* (BURR.) WINSL. et al.) differs from species to species. Nearly all cultivars of *P. communis* L. are susceptible to this disease. In contrast, several cultivars and selections of *P. pyrifolia* (BURM.) NAKAI are quite resistant. As early as 1873, 'Kieffer', a probable hybrid of the two species, was introduced. This cultivar combined some of the fruit characters of *P. communis* with the blight resistance of *P. pyrifolia*, thus demonstrating the possibility of using resistant clones in a breeding program. During the early 20th century, HANSEN (1915) and REIMER (1925) collected resistant clones of a number of species in the Orient. By 1930, several breeding programs were under way, in which *P. ussuriensis* MAXIM. and *P. pyrifolia* were being used as sources of resistance (ANDERSON, 1928; LANTZ, 1929; MAGNESS, 1937; MCCLINTOCK, 1929; PATTEN, 1917; WISKER, 1920).

On several occasions, however, *Pyrus* species, believed to be resistant, did not always transmit this characteristic to their progenies (LAYNE et al., 1968; THOMPSON et al., 1962). In addition, selections within the same species differed in degree of susceptibility to fire blight (REIMER, 1925). Because of these uncertainties in the value of any given selection as a source of resistance, it was necessary to examine available plant material for blight resistance before using it for breeding. Since 1960, when the USDA pear breeding program was expanded and additional emphasis was placed on *P. calleryana* DECNE. as a source of resistance (BROOKS et al., 1967), much of the available *Pyrus*

material was collected, examined, and rated for blight resistance. The results are reported here.

## MATERIALS AND METHODS

Two or more trees of several species, species hybrids and interspecific selections, were propagated on Bartlett seedling rootstock and planted in 1963 or 1964 at the USDA Plant Industry Station, Beltsville, Maryland. The trees were maintained in sod and fertilized, so that growth was vigorous and succulent.

Species and species hybrids were examined and classified according to leaf and fruit morphology. Those considered as true species were botanically similar to those trees maintained in the pear germplasm collection in Oregon (WESTWOOD et al., 1971). In *P. ussuriensis*, two groups are recognized: Group I, representing the true wild species, and Group II, which embraces the domestic hybrids between this and other species. The clonal selection *P. ussuriensis* 76, generally considered a *P. ussuriensis* × *P. pyrifolia* hybrid, is synonymous with Illinois 76 and is referred to by this name throughout the paper. Other accessions, received under a species name but later classified as hybrids, are listed separately from those accessions representing true species.

Certain clones of species and hybrids were used in crosses between 1962 and 1965. Seedlings obtained were planted in the field the following year, spaced 120 cm, apart in 90 cm double rows 4.80 m apart. These crosses consisted of three groups: (a) several cultivars or selections crossed with *P. calleryana* 'Bradford', (b) cultivars or selections of *P. communis* crossed with those of *P. ussuriensis*, and (c) two New Jersey selections (parentage 'Bartlett' × (*P. pyrifolia*) 'Meigetsu') back crossed to *P. communis* 'Bartlett', 'Ananas de Courtrai', and two US selections.

Fire blight occurred as natural infection and no attempt was made to prevent or control it by pruning or spraying. All trees in this study were subjected to several blight epiphytotics that occurred between 1967 and 1972. The incidence of blight was so severe that more than 98% of a world-wide collection of 522 cultivars became infected and resulted in severe damage to trees of 88% of these (OITTO et al., 1970). Each fall, individual trees were rated for total amount of damage according to the standard USDA blight scoring system (VAN DER ZWET et al., 1970). Scores, based mainly on age of wood infected and total percent of tree blighted, are a numerical code from 10 to 1, with the higher scores indicating the least damage. Classes of blight resistance were arranged as follows: highly resistant (scores 10–8), 0–6% of tree blighted; moderately resistant (scores 7–6), 7–25% of tree blighted; susceptible (score 5), 26–50% of tree blighted; and very susceptible (scores 4–1), 51–100% of tree blighted. The final rating is the lowest score assigned in any year.

## RESULTS

### *Species*

In this planting, the first record of fire blight was made in 1968 and continued through 1972. Of the 24 species and species hybrids tested, 20 (83.3%) received an average blight score of 5.6 or below, indicating considerable susceptibility (Table 1). However 40 (37.4%) of 107 clones rated 6.0 or better. With few exceptions, there was little

Table 1. Rating of pear species and species hybrids for resistance to fire blight.

| Pyrus species[1] | Number of clones | Number of clones in blight classes | | | | Mean blight score |
|---|---|---|---|---|---|---|
| | | 10–8 | 7–6 | 5 | 4–1 | |
| *P. amygdaliformis* VILL. | – | | | | | – |
| *P. amygdaliformis* hybrids | 4 | | | | 4 | 1.0 |
| *P. betulaefolia* BUNGE | 3 | | 1 | | 2 | 2.7 |
| *P. betulaefolia* hybrids | 16 | 2 | 2 | 1 | 11 | 2.8 |
| *P. calleryana* DECNE. | 9 | 6 | 2 | | 1 | 7.7 |
| *P. calleryana* hybrids | 7 | 2 | 2 | 1 | 2 | 6.0 |
| **P. canescens* SPACH. | 1 | | | | 1 | 1.0 |
| *P. communis* L. | 12 | | | | 12 | 1.0 |
| *P. communis* hybrids | 2 | | 1 | | 1 | 5.5 |
| *P. elaeagrifolia* PALL. | 1 | | | | 1 | 1.0 |
| *P. elaeagrifolia* hybrids | 2 | | | | 2 | 1.0 |
| **P. fascicularis* HORT. | 1 | | | 1 | | 5.0 |
| *P. hondoensis* NAK & KIK. | 4 | 2 | 1 | | 1 | 6.3 |
| *P. longipes* COSS. & DUR. | 2 | | | | 2 | 1.0 |
| **P. michauxii* BOSC | 1 | | | | 1 | 1.0 |
| *P. nivalis* JACQ. | 2 | | | | 2 | 1.0 |
| *P. nivalis* hybrids | 2 | | | | 2 | 1.0 |
| *P. pashia* D. DON. | – | | | | | – |
| *P. pashia* hybrids | 2 | | | 1 | 1 | 3.0 |
| *P. pyrifolia* (BURM.) NAK. | 8 | 2 | 4 | | 2 | 5.6 |
| *P. pyrifolia* hybrids | 3 | 1 | 1 | | 1 | 5.3 |
| *P. salicifolia* PALL. | 3 | | | | 3 | 1.0 |
| *P. serrulata* REHD. | 5 | | 3 | | 2 | 4.6 |
| **P. siniaca* THOUIN. | 1 | | | | 1 | 1.0 |
| *P. ussuriensis* MAXIM. | | | | | | |
| Group I | 5 | 4 | 1 | | | 9.4 |
| Group II | 11 | 2 | 1 | 2 | 6 | 4.3 |
| Totals | 107 | 21 | 19 | 6 | 61 | |

[1] Species marked with asterisk (*) are arboretum hybrid types not found as natural wild species.

difference in the blight reaction between pure species and hybrids of that species. Clones of the wild type *P. ussuriensis* (Group I) were the most resistant of all the species tested and received a mean blight score of 9.4. Eleven clones of the hybrid type (Group II) showed considerable susceptibility and received a mean score of 4.3.

Most accessions of *P. calleryana* also rated in the highly to moderately resistant blight classes. In addition, 4 of 7 accessions of *P. calleryana* hybrids were rated as resistant. When 439 open pollinated *P. calleryana* 'Bradford' seedlings were rated, the distribution was as follows: class 10–8, 42.3%; class 7–6, 19.1%; class 5, 9.1%; and class 4–1, 29.4%.

Two other species with predominantly resistant clones were *P. hondoensis* NAK. & KIKUCHI and *P. pyrifolia* (*P. serotina*). The latter species has been used extensively as a gene source for blight resistance (CARPENTER & SHAY, 1953; HOUGH, 1944; LAMB, 1960; LAYNE et al., 1968; SHAY et al., 1962; THOMPSON et al., 1962). However, many cultivars, with *P. pyrifolia* parentage such as 'Campas', 'Hawaii', and 'Twentieth Century', have died from blight at Beltsville (OITTO et al., 1970).

*Interspecific hybrids*

We rated 85 selections obtained through interspecific hybridization at the New Jersey Agricultural Experiment Station, New Brunswick. Since conditions are much more favorable for blight in Beltsville than in New Brunswick, it is not surprising that some of these selections had a low resistance score in Beltsville.

To simplify presentation, these selections are listed by parentage rather than by their selection number (Table 2). They are predominantly crosses between *P. communis* with *P. ussuriensis*, *P. pyrifolia* or their hybrids. Of the 36 accessions with *P. ussuriensis* parentage (Illinois 76 and 'Pai Li'), 63.9% of the clones were rated moderately to

Table 2. Rating of pear selections of New Jersey Agricultural Experiment Station for resistance to fire blight.

| Parentage of selection | | Number of clones | Number of clones in blight classes | | | | Mean blight score |
|---|---|---|---|---|---|---|---|
| | | | 10–8 | 7–6 | 5 | 4–1 | |
| *P. ussuriensis* | | | | | | | |
| Illinois 76 | × open pollinated | 3 | 3 | | | | 9.6 |
| Illinois 76 | × 'Favorita' | 5 | 4 | 1 | | | 9.4 |
| Illinois 76 | × P.I. 55805 | 2 | 1 | 1 | | | 7.5 |
| Illinois 76 | × 'Bartlett' | 13 | 8 | 1 | 1 | 3 | 7.0 |
| Illinois 76 | × 'Pai Li' | 1 | | 1 | | | 7.0 |
| Illinois 76 | × 'Duchess Angouleme' | 1 | | 1 | | | 6.0 |
| Illinois 76 | × 'Beurre Bosc' | 2 | | | 1 | 1 | 3.0 |
| 'Pai Li' | × 'Bartlett' | 1 | | | | 1 | 4.0 |
| 'Pai Li' | × 'Beurre Bosc' | 1 | | | | 1 | 4.0 |
| 'Pai Li' | × 'Duchess Angouleme' | 3 | | 1 | | 2 | 3.0 |
| 'Pai Li' | × 'Lincoln' | 4 | 1 | | | 3 | 3.0 |
| Total: | | 36 | 17 | 6 | 2 | 11 | |
| % of total: | | | 47.2 | 16.7 | 5.6 | 30.5 | |
| *P. pyrifolia* | | | | | | | |
| 'Okusankichi' | × 'Bartlett' | 1 | 1 | | | | 10.0 |
| 'Okusankichi' | × 'Gorham' | 4 | 1 | | 1 | 2 | 4.2 |
| 'Okusankichi' | × 'Clapp Favorite' | 1 | | | | 1 | 4.0 |
| 'Okusankichi' | × 'Worden Seckel' | 2 | | | | 2 | 1.0 |
| 'Meigetsu' | × 'Duchess Angouleme' | 2 | 2 | | | | 10.0 |
| 'Meigetsu' | × 'Worden Seckel' | 1 | 1 | | | | 9.0 |
| 'Meigetsu' | × 'Beierschmitt' | 5 | 3 | | | 2 | 5.8 |
| 'Meigetsu' | × 'Flemish Beauty' | 2 | 1 | | | 1 | 5.0 |
| 'Meigetsu' | × 'Clapp Favorite' | 3 | 1 | | 1 | 1 | 5.0 |
| 'Meigetsu' | × 'Bartlett' | 8 | 1 | 1 | | 6 | 2.5 |
| New Jersey 1 | × 'Clapp Favorite' | 4 | | 1 | 1 | 2 | 4.0 |
| New Jersey 1 | × 'Bartlett' | 5 | | 1 | | 4 | 3.0 |
| New Jersey 1 | × 'Beierschmitt' | 8 | | | | 8 | 1.3 |
| New Jersey 1 | × 'Worden Seckel' | 1 | | | | 1 | 1.0 |
| New Jersey 1 | × 'Gorham' | 1 | | | | 1 | 1.0 |
| New Jersey 1 | × 'Beurre Bosc' | 1 | | | | 1 | 1.0 |
| Total | | 49 | 11 | 3 | 3 | 32 | |
| % of total | | | 22.4 | 6.1 | 6.1 | 65.3 | |

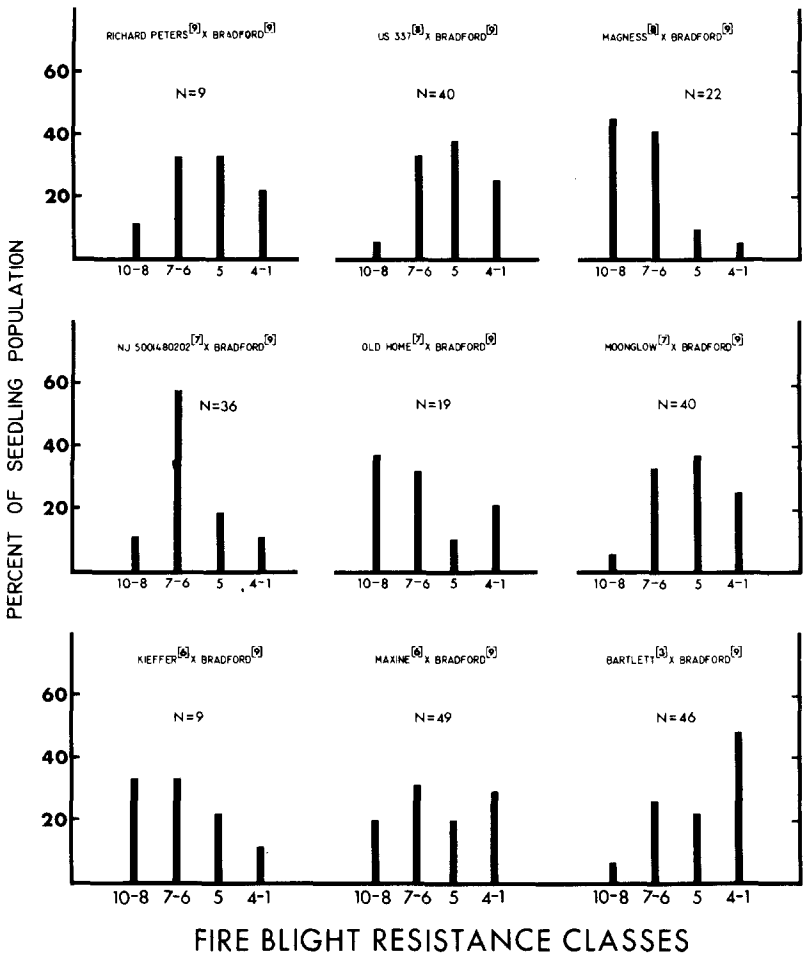


Fig. 1. Frequency distribution of fire blight resistance in progenies of interspecific *Pyrus* crosses with *P. calleryana* 'Bradford'. (Blight rating of parents is given in parentheses).

highly resistant. However, of the 49 clones with *P. pyrifolia* parentage ('Okusankichi', 'Meigetsu', or New Jersey 1), only 28.5% were in these resistance classes. With some exceptions. Illinois 76 and 'Meigetsu' produced a greater number of selections with blight resistance than the other three species.

*Seedling progenies*

Bradford pear with a blight rating of 9, is a highly resistant cultivar of *P. calleryana* but tends to be quite variable in transmitting this resistance to its progenies, depending upon the other parent (Fig. 1). When crossed with the resistant *P. communis* cultivars 'Magness' and 'Old Home', the percent of resistant to susceptible seedlings was 86–14% and 69–31%, respectively, with more than 38% in the highly resistant class 8–10. When crossed with 'Moonglow' and its sister seedling US 337, however, the percent was 62–38% for each with only 5% in the highly resistant class and 25% in the

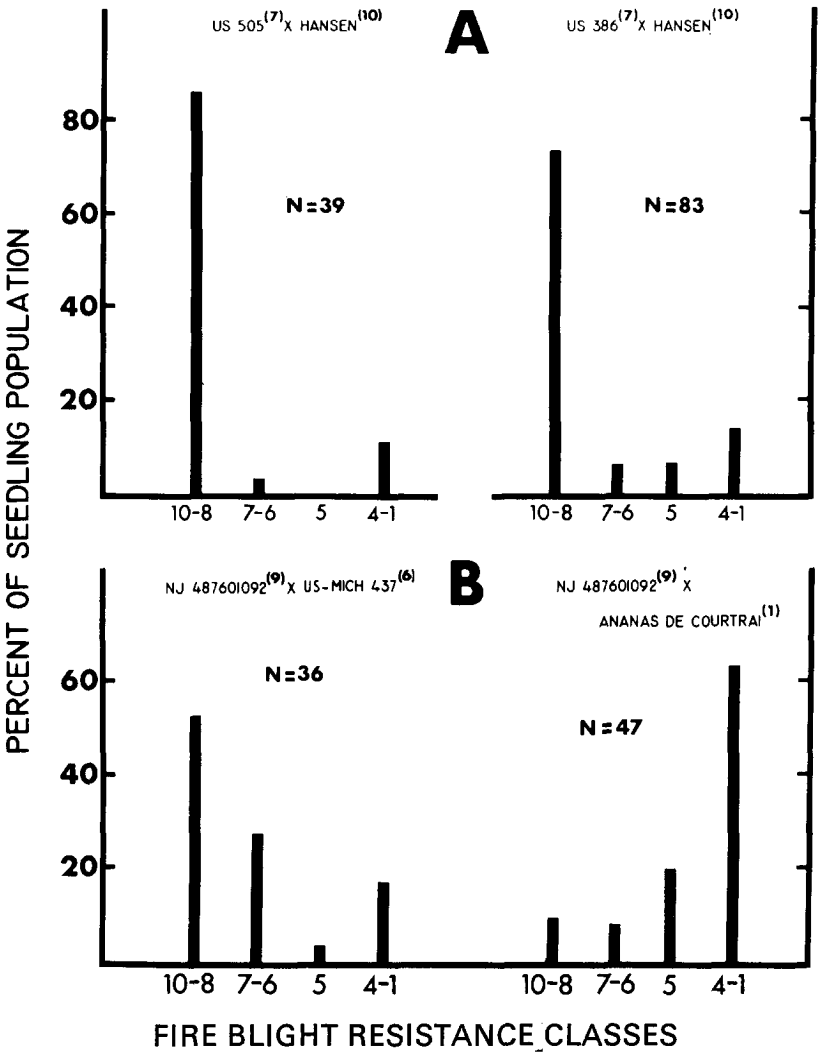


Fig. 2. Frequency distribution of fire blight resistance in progenies of interspecific *Pyrus* crosses with *P. ussuriensis*. A) US 386 and 505 = selections of *P. communis*; 'Hansen' = selection of *P. ussuriensis* (Group I). B) US-Mich. 437 = selection of *P. communis*; NJ 487601092 = selection from Illinois 76 × 'Bartlett'. 'Ananas de Courtrai' = cultivar of *P. communis*. (Blight rating of parents is given in parentheses).

very susceptible class 4–1. With Bartlett, which is very susceptible, the result was similar except that 48% of the seedlings fell into the very susceptible class.

'Hansen Siberian' is a highly blight resistant clone of *P. ussuriensis* and has tended to transmit this resistance to its seedling progenies. In crosses with *P. communis* selections US 505 and US 386, both rated 7 for blight, 90% and 75% of the seedlings, respectively, rated highly resistant and only 10% and 20%, respectively, were rated as very susceptible (Fig. 2-A).

Illinois 76 has been used by several breeders and has produced many blight resistant seedlings including NJ 487601092 (score 9), a selection from a cross between Illinois 76 and Bartlett. When this selection was crossed with US-Mich 437 (score 6), about 80% of the seedlings were in the resistance classes 6–10, including about 55% in the highly resistant class (Fig. 2-B). However, when crossed with very susceptible 'Ananas de Courtrai' (score 1), about 80% of the seedlings were in the susceptible classes with 62% being very susceptible and only 8% highly resistant. Thus, a cross of 2 resistant selections produced 47% more resistant seedlings than a cross between one of these selections and an extremely susceptible cultivar. It appears that a high degree of resistance in a female parent is not transmitted to the progeny when a very susceptible male parent is used.

Progenies of moderately resistant parents followed the same pattern. When two New Jersey sibling selections from identical parentage (Bartlett × Meigetsu), one blight susceptible and the other resistant, were both crossed with either resistant or susceptible cultivars, the percent of resistant to susceptible seedlings was nearly identical, despite their phenotypic blight rating (Fig. 3). It appeared that their genotypes may be more alike than their phenotypic reactions indicated. When they were crossed with the moderately resistant selections US 539 and US 387, the percent of very susceptible seedlings was 40%. With 'Bartlett' as the male parent, this percentage increased to 56%, and reached 72% with 'Ananas de Courtrai'. Since both Bartlett and Meigetsu are susceptible, it appeared that the combination with susceptible cultivars increased susceptibility in the progenies.

## DISCUSSION

It appeared that no pear species, cultivar, or selection is immune to fire blight. However, some genetic resistance was found in about 40% of the species in our collection. It is possible that resistant specimens would be found in all species if large enough populations were tested. Possibly many selections of the various species, which are morphologically classified as true to the species, are in fact hybrids, which may account for their resistance.

In principle we agree with REIMER (1925) that the five most important pear species, ranked in descending order of degree of blight resistance, are *P. ussuriensis*, *P. calleryana*, *P. betulaefolia*, *P. pyrifolia*, and *P. communis*. In each species, however, there is a range of resistance that makes it impossible to assign a certain degree of resistance to a given species.

Our experience indicates that variability in resistance within a species is great, but several clones and selections of the same species may possess different degrees of resistance. Therefore, it is necessary to test selections of a given species before they are used in a breeding program. Others have also noted variability in blight resistance within *P. betulaefolia*, *P. calleryana*, *P. pyrifolia*, and in Group II of *P. ussuriensis* (ANDERSON, 1928; CAMERON et al., 1968; LAMB, 1960; LAYNE et al., 1968; MOWRY, 1964; REIMER, 1925). Severe fire blight in *P. betulaefolia* has been reported (CAMERON et al., 1968; REIMER, 1925; TUKEY & BRASE, 1943), but REIMER (1925) found, among seedlings of this usually susceptible species, 18 that were highly resistant to fire blight.

In *P. pyrifolia*, degree of resistance ranged from very resistant to very susceptible.

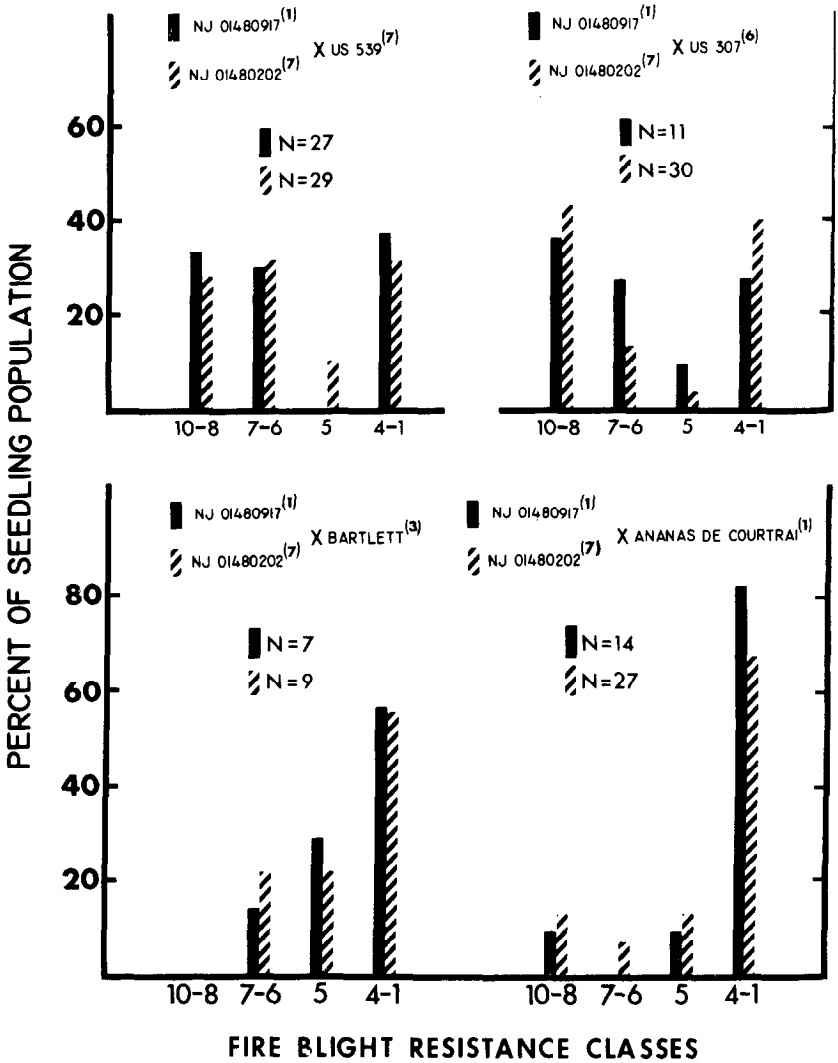


Fig. 3. Frequency distribution of fire blight resistance in progenies of interspecific *Pyrus* crosses with *P. pyrifolia*. NJ 5001480917 and 5001480202 = 'Bartlett' × 'Meigetsu' (*P. pyrifolia*); US 307 and 539 = selections of *P. communis*; 'Bartlett' and 'Ananas de Courtrai' = cultivars of *P. communis*. (Blight rating of parents is given in parentheses).

In *P. calleryana*, variability in resistance was observed among 270 seedlings in nine progenies from controlled pollinations as well as among a large population of open-pollinated 'Bradford' seedlings. We feel that susceptibility may be the result of hybridization of the original species with a very susceptible pollen parent, probably originating from *P. communis*.

$F_1$ hybrids of *P. calleryana* with *P. communis* cultivars, produced at Beltsville, are morphologically similar to *P. calleryana*, except for only slightly larger fruit size. Similar results have been reported for *P. ussuriensis* (LANTZ, 1929). It appears that

'Bradford', though phenotypically a highly resistant cultivar, contributes very little resistance to its progenies as even better resistance can be obtained from crosses between resistant cultivars of *P. communis*.

In previous tests of several cultivars and clonal selections of *P. ussuriensis*, those representing Group I ('Hansen', 'Ba Li Hsiang', 'Hsiang Sui Li', and 'Suan Li') all showed high resistance, whereas those in Group II ('Pai Li' and 'Ya Kuang Li') succumbed to blight (OITTO et al., 1970). This also underlines the possibility that cultivars closest to the wild type are more resistant to fire blight than hybrids with a susceptible parent.

Illinois 76 has been reported resistant to fire blight and of great value in pear breeding (HOUGH, 1944; MOWRY, 1964; SHAY et al., 1962; THOMPSON et al., 1962). LAYNE et al. (1968) reported, however, that in only 1 of 3 progenies was this selection outstanding in its ability to transmit a high level of resistance to its offspring. Our data indicate that a New Jersey selection from Illinois 76 transmitted a high level of resistance when crossed with moderately and very resistant parents. However, when crossed with extremely susceptible 'Ananas de Courtrai', almost no resistance was transmitted to the progeny. The fact that Illinois 76 blighted severely under natural conditions at Beltsville and that artificial inoculation in older branches resulted in severe fire blight (VAN DER ZWET, 1969) indicate that this clone is less resistant than previously reported. It appears therefore, that this selection, while phenotypically resistant, contains genes for susceptibility, for when crossed with a highly susceptible cultivar, produces a high percentage of susceptible offspring.

More New Jersey selections from crosses between *P. communis* cultivars and 'Pai Li' (*P. ussuriensis* hybrid) blighted than those from crosses between *P. communis* and Illinois 76. THOMPSON et al. (1962) reported similar results and suggested that resistance in Illinois 76 may be different from that derived from *P. pyrifolia*. In contrast, CARPENTER et al. (1953) and LAYNE et al. (1968) found that 'Pai Li' transmitted more resistance than Illinois 76.

Several factors have been suggested that may be responsible for the resistance of plants to bacterial pathogens (CAMERON et al., 1968; CHALLICE & WESTWOOD, 1972; HILDEBRAND et al., 1969; KLEMENT & GOODMAN, 1967). From all these and our data it appears that there may be more than one type of resistance represented among the several *Pyrus* species. If we may assume that fire blight was originally known only in North America where no native *Pyrus* species were found, the disease organism and host species evolved completely separate from each other. Thus blight resistance in any species or clone would be entirely fortuitous. Until the nature of resistance and the possible types of resistance mechanisms are completely elucidated, we suggest that pear breeders, using various species or species hybrids, do not mix breeding lines until fruit quality is improved by back crossing.

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