GENETIC RESISTANCE OF PORT-ORFORD-CEDAR (*CHAMAECYPARIS LAWSONIANA*) TO *PHYTOPHTHORA LATERALIS*: RESULTS FROM EARLY FIELD TRIALS

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ABSTRACT

Field trials of Port-Orford-cedar (*Chamaecyparis lawsoniana*) (POC) established by the USDA Forest (USFS), USDI Bureau of Land Management (BLM), and Oregon State University (OSU) at two sites in 1993 and three sites in 1998 provide early information on genetic resistance to a POC root pathogen, *Phytophthora lateralis*. This information adds to the results of an older small planting on the OSU Botany Farm. Family 510015 was the top survivor among the 28 open-pollinated families planted in 1993, with a mean survival of 50% versus a mean of 23% for all families through 1997. Family 510015 was also among the top performers in root lesion and branch lesion tests following artificial inoculations. In the 1998 plantings, crosses involving clones 510015 or CF1, or crosses involving progeny of 510015 were rated among the best for lesion score. CF1 had previously shown good survival in the older clonal planting on the OSU Botany farm where all susceptible clones have died. At this point only a few parents show relatively strong resistance, but screening of thousands of phenotypically resistant parents is underway. The underlying mechanisms of resistance are not known at this point.

INTRODUCTION

Port-Orford-cedar is an important forest tree species in southwestern Oregon and northwestern California. It also is susceptible to the root pathogen *Phytophthora lateralis*, which was first found in Port-Orford-cedar forests around 1952 (having been identified in horticultural nurseries as early as 1923). The spread of this exotic pathogen throughout the natural range continues each year, with trees often dying within a year of visible symptoms. Loss of these trees will alter some ecosystems in which this species plays an important role. The USDA Forest Service (USFS), USDI Bureau of Land Management (BLM), and Oregon State University (OSU) have been involved in a program to stop the spread of the disease, and to try to re-establish resistant Port-Orford-cedar in areas were heavy mortality has occurred. Genetic resistance to *P. lateralis* is one management tool that could play an important role, especially in restoration of Port-Orford-cedar to infected ecosystems. Current evidence indicates that the frequency of resistant trees in natural populations is very low. Several field plantings have been established from 1989 to 1998 to determine whether resistant genotypes identified in greenhouse screening trials or phenotypic selections from areas of high disease mortality also showed short-term or long-term resistance in the field.

MATERIAL AND METHODS:

1) 1989 planting: Resistant and non-resistant rooted cuttings and seedlings were planted at the OSU Botany Farm. This planting included rooted cuttings from six clones (18 - 25 cuttings per clone, distributed over four blocks), and open-pollinated seedlings from one of these clones (20 seedlings). This planting was evaluated yearly for mortality from *P. lateralis*. In spring 1999, branches from surviving trees were inoculated at Oregon State University to evaluate relative resistance using one of the short-term screening methods developed (the branch dip technique involves immersing six small branches per tree in a solution containing *P. lateralis* zoospores, and scoring branches for lesion length three weeks afterward).
2) 1993 planting: 28 open-pollinated seedling families (one-year old seedlings) were planted at two sites on the Siskiyou National Forest in Oregon. Seedlings were distributed over 16 blocks per site, with each family represented once per block (some families did not have enough seedlings for all blocks). Mortality has generally been scored once or twice a year since establishment. Twenty-seven of the parent clones of these families had been screened in 1989/1990 for resistance using a branch inoculation technique.
3) 1998 planting: 107 families (including four control crosses, six open-pollinated checklots, and 97 trees from throughout much of the range of POC that were not phenotypically selected for resistance) were established at three sites. Four to seven blocks (with four to six seedlings per family per block) were planted at each site. One of the sites includes four raised beds at OSU that have been inoculated with *P. lateralis*; the other two sites had Port-Orford-cedar naturally present that had been killed by *P. lateralis*. Four of the five blocks at Quosatana, and five of the seven blocks at Camas Valley were evaluated for relative amount of lesion present (lesion score) and percent of trees infected, by removing seedlings from soil several months after planting and examining the root system.

RESULTS

1) 1989 Botany Farm Planting:

- Mortality in the three susceptible clones was early and was nearly 100%, while the three resistant clones had 45 - 80% survival (Table 1); the one resistant seedling family showed 24% survival after 10 years in the field. The major portion of the mortality in the resistant clones (and family) occurred within the first two years, no new mortality occurred over the last five years (Figure 1).
- Lesion length was similar for the survivors within the resistant clones (Table 1).

TABLE 1. Ten year field survival and resistance testing mean lesion lengths

PARENT TREE	NUMBER PLANTED	% ALIVE 1999	STEM DIP SCORE (mm)
CF 1 cuttings	25	48%	18.1 (11, 12-22)*
CF 1 seedlings	20	24%	21.3 (6, 11-32)
CF 2	20	80%	25.2 (15, 14-48)
CB 1	20	45%	19.4 (8, 11-38)
CB 2	20	0%	-
CB 4	18	6%	45 (1)
CB 5	20	0%	-

* (number of trees tested and range of scores)

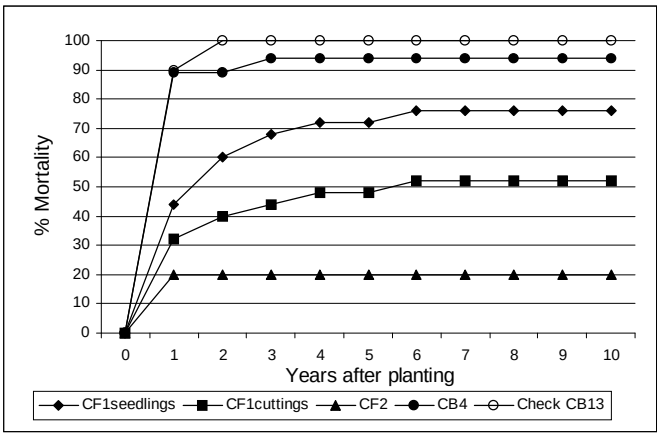

FIGURE 1. Clonal mortality percent at OSU Botany Farm planting.

2) 1993 Plantings (two sites):

- >50% mortality occurred in the first year, very little mortality has occurred between 1995 and 1997 (Figure 2)
- Mean mortality in April 1997 was 82% at Quosatana (Q), and 71% at Flannigan (F), but some families performed inconsistent over the two sites (Figure 3).
- In 1997, family 510015 had the lowest mortality at both sites (44% at Q, 56% at F), and no family had 100% mortality over both sites (Figure 3).
- The correlation of family mean mortality over these two sites with the 1989/1990 branch inoculation tests at OSU was low to moderate and varied somewhat by site and age of field assessment. The family mean correlation between the two sites was also low to moderate, depending on age (Table 2).

TABLE 2. Correlation of percent mortality between two sites

Months After Planting	Correlation
3	0.215
4	-0.213
7	0.194
14	0.104
19	0.408**
31	0.485**
39	0.526**
43	0.430**
49	0.321*

* sig. at $p \leq 0.1$ **sig. at $p \leq 0.05$

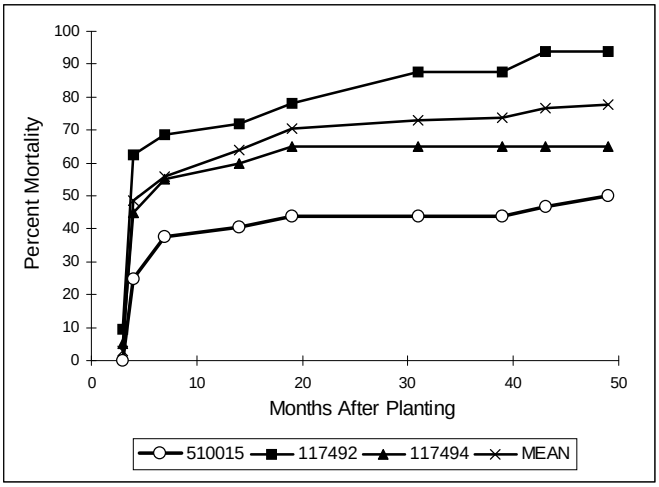

FIGURE 2. Cumulative percent mortality over two sites established in 1993 for three families and the mean of all 28 families.

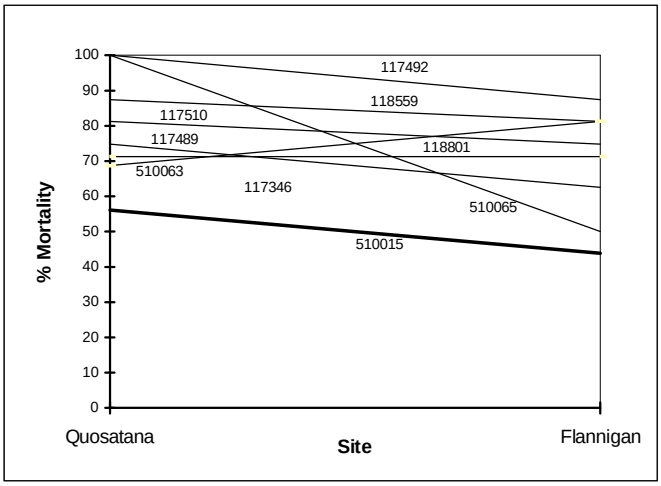

FIGURE 3. Comparison of percent mortality on two sites in April 1997 (49 months after planting).

3) 1998 Plantings (3 sites):

- Seedlings from the four control crosses, involving clones CF1, CF2, or progeny of 510015 as one or more parents were among the very best for resistance at all three sites (using lesion score or percent of trees infected). Open-pollinated progeny of 510015 also showed relatively small lesion scores at all sites
- Several of the "randomly" selected families had low lesion scores, particularly Quosatana (Figure 4).
- Nearly all families in the OSU raised beds had a very high percentage of trees infected (Figure 4), and relatively high lesion score.
- Family mean correlations across sites were low to moderate, and varied depending on the sites and whether the checklots were included (Table 3).

TABLE 3. Correlations between family mean lesion codes between three field test sites.

	Camas Valley	Quosatana	OSU Raised Beds
Camas Valley		0.292**	0.524**
Quosatana	0.118		0.297**
OSU Raised Beds	0.389*	0.041	

Above diagonal n = 107
Below diagonal n = 97 (excludes checklots)

DISCUSSION

The relatively high survival after 10 years in the field of some clones at the OSU Botany Farm is encouraging. However, the reason for the early mortality from *P. lateralis* of some ramets of these resistant clones is unexplained at this point.

Results to-date indicate that there is a very low frequency (perhaps <1%) of phenotypic selections from natural populations that exhibit strong resistance similar to the best clones at the OSU Botany farm.

Information on the types and numbers of resistance mechanisms is not available at this point.

The best selections to date appear to rate highly for resistance regardless of screening method. Recent efforts in the resistance program have concentrated on branch lesion testing from thousands of phenotypic selections. Many of the top 10% of selections from this technique will be evaluated with a root test to confirm resistance.

The low correlations among the three sites planted in 1998 are disappointing, and may be due to an array of factors, including magnitude and nature of the resistance in most of the "random" families, the type of assessment made in 1998, infection level, and the timing of the assessment at the three sites.

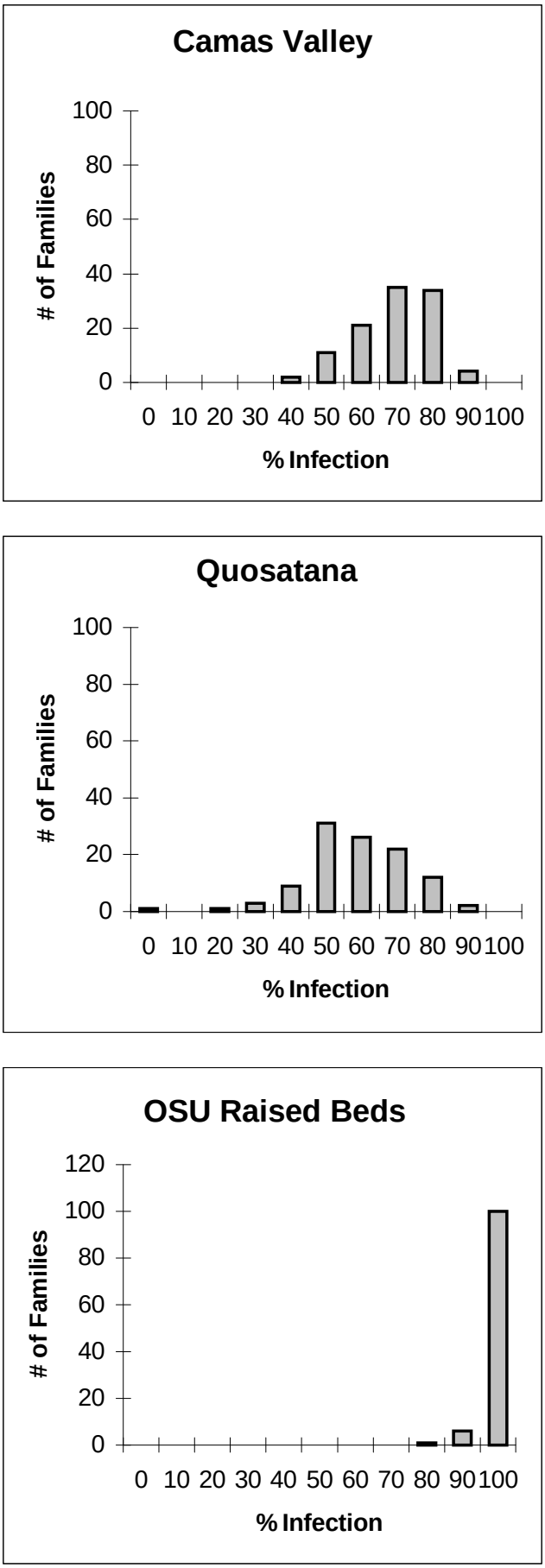

FIGURE 4. 1998 Field site distribution of family mean percent infection.

ACKNOWLEDGEMENTS

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