

# Progress in Research on Systemic Induced Resistance in Austrian Pine Against Shoot Blight (Formerly Known as *Diplodia* Tip Blight)

Pierluigi (Enrico) Bonello, James T. Blodgett, and Daniel A. Herms

**Note:** Pine shoot blight (pathogen: *Sphaeropsis sapinea*) is the new name for *Diplodia* tip blight (pathogen: *Diplodia pinea*).

## Introduction

Pine trees and their diseases are much more important to the nursery industry than is often realized. The wholesale value of the nursery industry in the United States was \$3,096,723,000 in 1998 (USDA 1998). Pines are the fourth largest selling species in nursery sales, with 30,068,000 plants produced annually for a total value of \$108,840,000 (USDA 1998). Once pines are placed in the landscape and achieve ages of approximately 15 to 18 years, their values exceed \$200 per tree, or a total estimated landscape value of approximately \$6 billion.

In Ohio, the nursery/ornamental industry is estimated to have a value of \$2.4 billion. Wholesale production of ornamental plants

in Ohio exceeded \$500 million in 1999, accounting for 12% of total agricultural production in the state, and making it Ohio's fourth leading agricultural commodity behind corn, soybeans, and milk (Randall *et al.*, 2000). Additionally, cash receipts for Ohio's landscape and garden center industries exceeded \$1.5 billion dollars in 1996 (Rhodus, 1997).

Pines suffer major losses from plant diseases and insect pests. Historically, pesticides have been widely used to manage these problems of ornamental plants. For example, more than 27 million U.S. households used pesticides in 1989 to control pests of lawns, trees, and gardens (Raupp, Koehler, and Davidson, 1992). Because pesticide use can create risks to human health, the Food Quality Protection Act is restricting their use. This has increased the need for the development of alternative pest management strategies. In fact, the Ohio Nursery and Landscape Association (ONLA) rates the development of new and alternative IPM techniques and environmentally safe pesticides as the two top horticultural research needs.

Although plant disease resistance has been recognized as an ideal strategy for managing pests of ornamental plants and shade trees for many years, little progress has been made in the deployment of disease-resistant ornamental plants, or in understanding their resistance mechanisms

---

Pierluigi (Enrico) Bonello, The Ohio State University, Department of Plant Pathology; James T. Blodgett, The Ohio State University, Department of Plant Pathology; and Daniel A. Herms, The Ohio State University/Ohio Agricultural Research and Development Center/Entomology.

(Herms, in press; Raupp, Koehler, and Davidson, 1992). If host-pest interactions were better understood in ornamental trees, it would be possible to manipulate them to minimize pest problems while reducing pesticidal inputs (Herms, Akers, and Nielsen, 1984). However, few studies have investigated these interactions in any detail.

Pines are affected by numerous diseases, particularly those caused by fungi, that often severely limit their ecological, environmental, and commercial value (Harrington and Wingfield, 1998). Some diseases also predispose trees to insect infestations. Thus, there is a clear incentive to minimize the negative impacts of fungal diseases on the health and productivity of pines in managed situations. A better understanding of the basic physiological and biochemical processes that influence the outcome of host parasite interactions in pines, and how these are affected / modulated by environmental variables, can contribute significantly to this objective. Systemic induced resistance can protect plants against both insects and pathogens. This is one reason why we are studying this approach to resistance in pines.

## Systemic Induced Resistance

Systemic resistance can be induced in many plants by pathogens, chemicals, and by some beneficial microorganisms such as specific *Trichoderma* fungi and bacteria that colonize roots. This is how composts can induce resistance to foliar diseases in some plants. It is a subtle but important effect. This phenomenon is termed Systemic Induced Resistance (SIR).

Extensive research has been carried out in the last 20 years, and particularly in the last decade, to understand SIR. Most of the work has been conducted on herbaceous model plants, particularly tobacco and *Arabidopsis*, as these systems are quite

responsive to genetic manipulation (Buell, 1999). This has resulted in the development of chemical inducers of resistance such as Actigard. SIR-type responses have been observed in pine also (Bonello, Gordon, and Storer, 2001).

In contrast to the rather extensive studies in herbaceous plants, there are, to our knowledge, no detailed data on these processes for conifers other than the studies described herein. Only one example of chemical induction of resistance in pines is known (Reglinski, Stavely, and Taylor, 1998).

## Vigor and Disease Resistance

Little is known about how soil nutrients affect pine diseases. In a survey of red pine (*Pinus resinosa*) and jack pine (*P. banksiana*), tree mortality attributed to *Sphaeropsis sapinea* was as high as 30% for red pine and 51% for jack pine (Nicholls and Ostry, 1990). Such high mortality levels were attributed to, among other factors, poor site conditions.

However, in another field survey of red pines, mortality was correlated with paper-mill waste application and linked to higher foliar nitrogen in the treated stands (Stanosz and Trobaugh, 1996). Van Dijk *et al.* (1992) also correlated increased disease development by *S. sapinea* with high soil nutrient concentrations.

Although losses to *S. sapinea* have been associated with nutrient conditions, results are based on field observations and field surveys. These observations and surveys do not provide information on the quantitative effects of nutrition on disease development and cannot separate the effects of nutrients from many other possible environmental factors. Thus, basic studies must be performed. Preliminary data recently generated in our program have begun to answer some of these questions.

## Sphaeropsis Shoot Blight of Austrian Pine

Austrian pine (*P. nigra*) is endemic to the Mediterranean basin (Barbero *et al.*, 1998), but it was one of the first tree introductions to the United States and was first reported in cultivation in 1759 (van Haverbeke, 1990). Today this species is commonly planted as an ornamental in the United States.

Sphaeropsis shoot blight and canker, caused by *Sphaeropsis sapinea* (formerly known as *Diplodia pinea*, the cause of Diplodia tip blight), has resulted in extensive damage to conifers throughout the world. Pines in Ohio and the rest of the Midwest are extensively affected by this disease. The pathogen also causes crown wilt, collar rot, and root disease. Pines are affected from seedling stage to mature size and damage occurs in natural stands, nurseries, Christmas tree and ornamental plantings, and in plantations (Chou, 1976; Gibson, 1979; Nicholls, Ostry, and Prey, 1977; Stanosz and Cummings Carlson, 1996).

### Recent Progress in SIR Research in Pines

In recent experiments, trees were first inoculated in the lower stems. Later inoculation higher on the stem resulted in smaller lesions on trees that were inoculated at the base with *S. sapinea* compared with trees that were not inoculated at the base (i.e., the controls). This study confirmed that SIR occurs in this pine species as well as in Monterey pine (Bonello, Gordon, and Storer, 2001).

We also have preliminary data that show systemic accumulation in the induced trees, described previously, of chemicals active in resistance in pine trees, which further proves that we are measuring resistance and not some other unknown phenomenon

(Blodgett and Bonello, 2001).

Lastly, we have recently found that fertilization of red pine trees with an N-P-K fertilizer in controlled field experiments significantly increased the severity of *Sphaeropsis* tip blight. Thus, higher host vigor (evident from superior growth rates of fertilized trees) appeared to increase disease susceptibility in this pine. These studies will be replicated with Austrian pine.

### Conclusion

Our preliminary results, coupled with some of our previous research (Bonello, Gordon, and Storer, 2001), show that inducible defensive systems are not limited to herbaceous plants. Thus, systemic induced resistance, modulated by vigor, could potentially be developed into a viable pest management system for pines that is not solely reliant on fungicides. In the long run, a better understanding of these processes in our model system will allow for the development of integrated approaches to management of pests of other important woody ornamentals, in both the nursery and the landscape.

### Acknowledgments

We thank Maria Bellizzi for technical help and Harry Hoitink for critically reviewing the manuscript. Funding for the preliminary work was provided in part by the Ohio Agricultural Research and Development Center (OARDC) Research Enhancement Competitive Grants Program.

### Literature Cited

Barbero, M., R. Loisel, P. Quezel, D. M. Richardson, and C. P. Romaine. 1998. Pines of the Mediterranean basin. In: *Ecology and Biogeography of Pinus*, edited by D. M. Richardson. Cambridge: Cambridge University Press.

- Blodgett, J. T., and P. Bonello. 2001. Systemic induction of ferulic acid and other phenolic compounds in *Pinus nigra* inoculated with *Sphaeropsis sapinea*. *Phytopathology* 91 (6 Supplement):S9.
- Bonello, P., T. R. Gordon, and A. J. Storer. 2001. Systemic induced resistance in Monterey pine. *Forest Pathology* 31:99-106.
- Buell, C. R. 1999. Genes Involved in Plant-Pathogen Interactions. In: *Induced Plant Defenses Against Pathogens and Herbivores*. Edited by A. A. Agrawal, S. Tuzun, and E. Bent. St. Paul, Minn.: APS Press.
- Chou, C. K. S. 1976. A shoot dieback in *Pinus radiata* caused by *Diplodia pinea*. II. Inoculation studies. *New Zealand Journal of Forestry Science* 6:409-420.
- Gibson, I. A. S. 1979. *Diseases of Forest Trees Widely Planted as Exotics in the Tropic and Southern Hemisphere. Part II. The Genus Pinus*. Kew, UK: Commonwealth Mycological Institute.
- Harrington, T. C., and M. J. Wingfield. 1998. Diseases and ecology of indigenous and exotic pines. In: *Ecology and Biogeography of Pinus*. Edited by D. M. Richardson. Cambridge: Cambridge University Press.
- Herms, D. A., in press. Strategies for deployment of insect resistant ornamental plants. In: *Mechanisms and Deployment of Resistance in Trees to Insects*. Edited by M. R. Wagner, C. Clancy, T. Paine, and F. Lieutier. Dordrecht, The Netherlands: Kluwer Academic Publishing.
- Herms, D. A., R. C. Akers, and D. G. Nielsen. 1984. The ornamental landscape as an ecosystem: implications for pest management. *Journal of Arboriculture* 10 (11):303-307.
- Nicholls, T. H., and M. E. Ostry. 1990. *Sphaeropsis sapinea* cankers on stressed red and jack pines in Minnesota and Wisconsin. *Plant Disease* 74:54-56.
- Nicholls, T. H., M. E. Ostry, and A. J. Prey. 1977. *Diplodia pinea* pathogenic to *Pinus resinosa*.
- Randall, A., A. E. Lines, E. Liu, J. Ramey, and W. F. Matthews. 2000. 1999 Ohio Farm Income. The Ohio State University. Ohio Agricultural Research and Development Center.
- Raup, M. J., C. S. Koehler, and J. A. Davidson. 1992. Advances in implementing integrated pest management for woody landscape plants. *Annual Review of Entomology* (37):561-585.
- Reglinski, T., F. J. L. Stavelly, and J. T. Taylor. 1998. Induction of phenylalanine ammonia lyase activity and control of *Sphaeropsis sapinea* infection in *Pinus radiata* by 5-chlorosalicylic acid. *European Journal of Forest Pathology* 28:153-158.
- Rhodus, T. *Ohio Green Goods Industry Survey 1997*. Available from <http://www.hcs.ohio-state.edu/greengoods/greengoods.html>.
- Stanosz, G. R., and J. Trobaugh. 1996. Can fertilization with paper mill waste sludge threaten forest health and productivity? Shoot blight and canker found in treated red pine stands. *Pulp & Paper Canada* 97:151-154.
- Stanosz, G. R., and J. Cummings Carlson. 1996. Association of mortality of recently planted seedlings and established saplings in red pine plantations with *Sphaeropsis* collar rot. *Plant Disease* 80:750-753.
- USDA. 1998. USDA Census of Agriculture: 1998. Census of Horticultural Specialties, Vol. 2.
- van Dijk, H. F. G., M. van der Gaag, P. J. M. Perik, and J. G. M. Roelofs. 1992. Nutrient availability in Corsican pine stands in the Netherlands and the occurrence of *Sphaeropsis sapinea*: a field study. *Canadian Journal of Botany* 70:870-875.
- van Haverbeke, D. F. 1990. *Pinus nigra* Arnold. European Black Pine. In: *Silvics of North America*. Washington, D.C.: USDA Forest Service.