Paul E. Nelson Memorial Symposium

Edited by Brett A. Summerell, John F. Leslie, David Backhouse, Wayne L. Bryden, and Lester W. Burgess

Fusarium

Paul E. Nelson Memorial Symposium

Edited by
Brett A. Summerell, John F. Leslie,
David Backhouse, Wayne L. Bryden,
and Lester W. Burgess

APS PRESS
The American Phytopathological Society
St. Paul, Minnesota

Dedicated to the memory of Paul E. Nelson

Cover images: *Phoenix canariensis* palms infected with *Fusarium oxysporum* and macroconidia of *Fusarium chlamydosporum* (Courtesy S. Bullock) and molecule of fumonisin B_1 (Courtesy A. E. Desjardins and R. H. Proctor [Chapter 4]).

These chapters are either revised versions of papers presented at the Paul E. Nelson Memorial Symposium held at Pennsylvania State University, State College, Pennsylvania, on November 1997 or are submitted contributions written for this volume.

This book has been reproduced directly from computer generated copy submitted in final form to APS Press by the editors of the volume. No editing or proofreading has been done by the Press.

Reference in this publication to a trademark, proprietary product, or company name by personnel of the U.S. Department of Agriculture or anyone else is intended for explicit description only and does not imply approval or recommendation to the exclusion of other that may be suitable.

Library of Congress Catalog Card Number: 00-111693
International Standard Book Number: 0-89054-268-6

© 2001 by The American Phytopathological Society

All rights reserved.
No part of this book may be reproduced in any form, including photocopy, microfilm, information storage and retrieval system, computer database, or software, or by any means, including electronic or mechanical, without written permission from the publisher.

Copyright is not claimed in any portion of this work written by U.S. government employees as part of their official duties.

Printed in the United States of America on acid-free paper

The American Phytopathological Society
3340 Pilot Knob Road
St. Paul, Minnesota 55121-2097, USA

Chapter 16

DISEASES OF PINES CAUSED BY THE PITCH CANKER FUNGUS

L. David Dwinell, S. W. Fraedrich and D. Adams

Introduction

Fusarium subglutinans f. sp. *pini*, the pitch canker fungus, causes a number of serious diseases of *Pinus* species. The pathogen infects a variety of vegetative and reproductive pine structures at different stages of maturity and produces a diversity of symptoms. When the pathogen infects the woody vegetative structures of its pine host, the host-pathogen interaction causes resinous cankers, and the resultant disease is referred to as pitch canker. The pitch canker fungus also causes the mortality of female flowers and mature cones, and deteriorates seeds of several pine species, and can cause mortality of pine seedlings in nurseries. The involvement of insects, interaction with other pine diseases, and the marked influence of biotic and abiotic factors can greatly influence the incidence and severity of infections by *F. subglutinans* f. sp. *pini*.

The fungus

The causal fungus has gone through a number of name changes. In 1946, when pitch canker was first described, it was referred to as an undescribed species of *Fusarium* belonging in the Section Liseola. (16). Three years later, it was designated *F. lateritium* f. sp. *pini* (27). In the 1970's, the most common isolates of *Fusarium* from pitch canker tissue had abundant microconidia on sympodially branching conidiophores and no chlamydospores, and were assigned to *Fusarium moniliforme* var. *subglutinans* in the section Liseola (11,12,19). Kuhlman *et al.* (19) successfully paired isolates from pine with the compatible isolates of *Gibberella fujikuroi* var. *subglutinans* from India to provide further evidence that the pitch canker isolates were *F. moniliforme* var. *subglutinans*. In 1983, the variety was raised to species level as *F. subglutinans*. Correll *et al.* (7) concluded that there was considerable justification for assigning strains of *F. subglutinans* pathogenic to pines to a specific forma specialis. This conclusion is supported by virulence, genetic analysis, and composite RAPD data that suggests that pine isolates originated from the same gene pool (30). The pitch canker pathogen is currently designated *F. subglutinans* f. sp. *pini*.

This chapter is in the public domain and not copyrightable. It may be freely reprinted with customary crediting of the source. The American Phytopathological Society, 2001.

Pitch canker

Pitch canker was first reported in 1946 on Virginia pines (*P. virginiana*) in North Carolina. The name of the disease is derived from the copious pitch flow associated with most cankers (16). The classic symptom is a bleeding, resinous canker of the trunk, terminals, large branches, and exposed roots. The bark is retained on the cankers and the wood beneath the canker is deeply resin-soaked (11,12,16). Dieback in the upper crown results from cankers forming on the branches or shoots. As the branches or shoots are girdled by the fungus, the needles turn yellow to reddish brown; they later turn greyish brown to dark gray (11). The pitch-soaked wood is a diagnostic character useful in separating pitch cankers from most other maladies of pines (12,16).

The symptoms of pitch canker vary by pine host and forest management practices (12). For example, trunk and branch cankers are the most common on Monterey (*P. radiata*), Virginia, longleaf (*P. palustris*), and eastern white (*P. strobus*) pines. Shoot dieback is common on slash (*P. elliottii* var. *elliottii*), loblolly (*P. taeda*), shortleaf (*P. echinata*), sand (*P. clausa*), and Monterey pines (8,12). Trunk cankers on slash pine are common in seed orchards and are usually associated with the use of tree shakers for cone removal (11). Cankers on exposed roots can be found on slash pine in seed orchards and landscape plantings and on Monterey pine in landscape settings. In Mexico, for example, trunk cankers occur on *P. estevezi* and *P. pseudostrobus;* whereas, branch and shoot dieback are the common symptoms on *P. douglasiana*, *P. leiophylla*, and *P. arizonica* var. *stormiae* (Dwinell, unpublished; 26). Dieback and trunk cankers were found on Luchu pine (*P. luchuensis*) on two islands of Japan - Amamiooshima and Okinawa (23,24).

Incidence and Distribution From 1945 to 1973, limited outbreaks of pitch canker were noted in the southeastern United States, but the disease was not considered to be economically important. In 1974, a shoot dieback caused by the pitch canker fungus reached epidemic proportions on slash pine in Florida plantations and seed orchards, and on loblolly pine in seed orchards in North Carolina and Mississippi (11,12). These outbreaks spawned considerable research on pitch canker. Over the past two decades, pitch canker outbreaks in the South have occurred sporadically in time and place (12). Most, if not all, southern pines are considered to be suspects of the pitch canker pathogen. Pitch canker disease on southern pines extends from Virginia to southern Florida and west to eastern Texas.

Until the late-1980's, pitch canker was thought to be primarily a problem on pines in the southeastern United States. In 1986, pitch canker was recognized as a major component of dieback and mortality of Monterey pine in California (21). Pitch canker was unknown in California until disease outbreaks on planted Monterey pines occurred almost simultaneously at three widely-separated geographical locations (Santa Cruz, Hayward, and Santa Barbara). Subsequent surveys have found the disease extends from Mendocino County to San Diego;

however, the disease is most severe in central coastal California (1), particularly Santa Cruz and Monterey counties (1,29). In southern California, the disease is found largely in Monterey pine Christmas tree plantations (28) and ornamental plantings (D. Adams, unpublished).

Although the pathogen has also been recovered from several pine species native to California (1,8,28) as well as Douglas-fir (*Pseudotsuga menziesii*) (28), the greatest damage has been to Monterey pines. The extensive dieback and mortality of Monterey pine has all the characteristics of an introduced disease in California. This concept is also supported by research on the genetic diversity of vegetative compatibility groups in California populations of *F. subglutinans* f. sp. *pini* (7). Furthermore, unlike in the southeastern United States where pitch canker is not a problem in native stands (12), the disease has become established in the natural populations of Monterey pine in California at Point Año Nuevo, on the Monterey Peninsula and at Cambria. (28). Pitch canker is a severe threat to the Monterey pine genetic resource worldwide.

Until the late-1980's, the only report of pitch canker from outside the United States came from Hepting and Roth (17) who wrote that the disease "was found to be abundant in Haiti on *P. occidentalis* in February 1953". In the late-1980's, pitch canker was identified as causing trunk cankers and dieback of luchu pine on Amamiooshima and the Okinawa islands of Japan (23,24). At about the same time, pitch canker was identified in Mexico. The disease is prevalent on planted *P. halepensis* and *P. radiata* and in natural stands of *P. douglasiana*, *P. leiophylla*, P. *durangensis* and other pine species (26). In 1995, pitch canker was observed on *P. estevezi* in a plantation and *P. arizonica* var. *stormiae* in a natural stand in the State of Nuevo Leon (Dwinell, unpublished). Most recently, questions have arisen regarding the possible damage of radiata pine plantations by *F. subglutinans* f. sp. *pini* in the Basque Country of northern Spain (J. Aguirre, personal communication). The introduction of the pitch canker fungus into countries, such as New Zealand, Australia and Chile, that have extensive plantations of *P. radiata* could be disastrous.

Infection Any fresh wound, regardless of cause or location, provides an infection court for the pathogen. Insects can create wounds which can be infected by airborne spores of the pathogen or serve as vectors. In the southeastern United States, the deodar weevil (*Pissodes nemorensis*) (5) and the pine-tip moth (*Rhyacionia* spp.) (20) create wounds that may become infected by airborne spores of the pathogen.

Monterey pine is reputed to have more insects associated with it than any other pine species. In California, Fox *et al.* (13) reported that *Ips mexicanus* and *I. paraconfusus* can transmit the pitch canker fungus to Monterey pines. A plethora of other insects, such as species of *Pityophthorus* (twig beetles), *Conophthorus* (cone beetles), *Ernobius*, *Pissodes* (pine weevils), and *Aphrophora* (spittlebugs) appear to play a role in the disease complex in California. Dieback due to twig beetles is common on Monterey pines and can readily be confused with pitch

canker. The cause of the dieback can be determined by removing the outer bark from the dead or dying shoot and determining if signs of the insect are present or if the underlying wood is resin-soaked, a characteristic of pitch canker.

In slash pine seed orchards, main stem cankers often develop following injury caused by mechanical cone harvesters. Furthermore, weather-related injuries caused by wind and hail may serve as entry points. Hurricanes and tornadoes, in particular, have contributed to the intensification of the disease in some seed orchards (12).

Inoculum seems to be available in all seasons. In Florida, Blakeslee et al. (5) reported that the sporodochia containing the macroconidia occurred routinely on infected branches within the upper crown of infected trees during the entire year. Sporodochia can also occasionally be found on infected shoots of *P. radiata* in California (Dwinell, unpublished) and Mexico (26). In a loblolly pine seed orchard Kuhlman *et al.* (18) found spores of the pitch canker fungus through out the growing season on dead branches in the crown, in rainwater falling through infected trees, and in the air. Fraedrich and Dwinell (14) reported that *F. subglutinans* f. sp. *pini* was primarily detected in spore traps beneath asymptomatic longleaf pine trees during the nights when a rain occurred. In California, airborne inoculum of *F. subglutinans* f. sp. *pini* was detected through the year in an area with a high incidence of pitch canker disease in Monterey pine but not in areas where the disease was absent (8). A bark wash survey conducted on the central coast of California revealed that where the disease was present, both symptomatic and asymptomatic trees could test positive for the presence of spores of the pitch canker fungus (1).

The pitch canker fungus is frequently an ecological component of fusiform rust galls on southern pines. Hepting (15) suggested that some of the greatest damage resulting from fusiform rust, caused by *Cronartium quercuum* f. sp. *fusiforme*, resulted from the rust being followed by *Dioryctria* and the pitch canker *Fusarium*. Dwinell and Barrows-Broaddus (9) found that *F. subglutinans* f. sp. *pini* rapidly colonized rust-infected tissue and hastened morality of slash and loblolly pine seedlings. Infection of rust galls by the pitch canker fungus further weakens stems of mature trees and increase chances of breakage and tree mortality. In the late-1980's, Dwinell (unpublished) was unable to isolate the pitch canker *Fusarium* from galls caused by *Peridermium harknessii* on Monterey pine collected from outside the zone of infestation in California. Most recently, rust galls were found on Monterey pines at Point Año Nuevo with pitch canker symptoms (D. Adams and D. Dwinell, unpublished).

Damage Pitch canker is a dynamic disease. Each outbreak in a specific location has its own unique case history (or sequence of events) (12). Southern pines recover from shoot dieback, but stem and branch cankers are usually perennial. Factors that drive the disease in loblolly pine seed orchards are different from those that impact slash pine in plantations.

Pitch canker on Monterey pine in California acts like an introduced disease; whereas, pitch canker in the Southeast is considered endemic.

Damage to pines by *F. subglutinans* f. sp. *pini* includes tree mortality, growth suppression, and stem deformation. The annual mortality in the southern United States is low. Southern pines, particularly loblolly, pond (*P. serotina*), and shortleaf pines, generally recover from outbreaks of shoot dieback (4,12). In California, the mortality of Monterey pines resulting from infection by the pathogen, bark or twig beetles or both has not been quantified. Engraver beetles (*Ips* spp.) and chain saws tend to eliminate trees before the disease kills them.

Disease Management Because each outbreak has its own unique history, no specific management strategy has been developed to reduce or eliminate the threat of the pitch canker disease. An integrated management approach, including chemical control, biocontrol, genetic selection for resistance, and altered cultural practices, should be considered (12).

Because wounds serve as infection courts for the pitch canker fungus, understanding the cause(s) of wounds is tantamount to managing pitch canker (12). In cases where the wounding agent is an insect, chemical control may reduce disease intensification. Federal and State regulations on the use of chemical pesticides has, however, severely limited this option. Variation in the incidence of pitch canker is very common among clones within seed orchards suggesting that genetic selection for resistance is quite possible (4,12). Monterey pine resistance has been confirmed by artificial field inoculations. The long-term management of Monterey pine in California may be dependent on the development of resistant varieties (28).

Nurseries

Pitch canker is a problem at bareroot and container nurseries. Diseased pine seedlings show chlorotic or reddish brown needles and wilting. Pitch-soaked lesions usually occur at or near the soil line but occasionally are found in the region of the cotylendonary node (2). In a North Carolina nursery, mortality of shortleaf pine seedlings in 1994 was attributed to *F. subglutinans* f. sp. *pini* (M. Cram, personal communication). The pitch canker fungus has also been associated with late-season mortality in bare-root and containerized longleaf pine nurseries (6). It has been concluded that the pitch canker fungus is a wound pathogen of longleaf pine seedlings (6,14). At present, information about the wounding agents that occur naturally in bare-root and containerized longleaf pine nurseries in limited. The pitch canker fungus may be responsible for extensive mortality of radiata pine seedlings in nurseries in northern Spain (J. Aguirre, personal communication).

The pitch canker fungus has been found to cause root rot of containerized *P. patula* seedlings in a forest nursery in South Africa (29,30). This pine species in native to Mexico and was introduced to South Africa in 1907 (25).

Cones and seeds

The pitch canker fungus causes mortality of female flowers and mature cones and deterioration of seeds of several pine species (10, 22). Infected loblolly pine cones tend to be misshapen and smaller than normal. Some infected loblolly pine cones have a necrotic tip characterized by internal resin pockets (3). Dwinell and Fraedrich (10) isolated *F. subglutinans* f. sp. *pini* from the surface and interior of immature shortleaf pine cones from a North Carolina seed orchard. They further concluded that interior contamination by the pitch canker fungus was not correlated with necrotic regions, caused primarily by insects, on the cone surface. The mode of entry of the fungus, a wound parasite, is not known.

The pitch canker fungus is frequently associated with the seeds of southern pines. There have been occasions when entire slash pine seed lots or an entire longleaf pine seed crop has been lost because of low viability and germination caused by infection of the seeds by *F. subglutinans* f. sp. *pini* (12). Current research is targeted at determining if the pathogen is largely on the seed surface or if it infects the embryo. In the case of longleaf and shortleaf pines, the contamination is mostly on the seed surface (10,14). For example, in shortleaf pine it was found that 61% of the seeds were contaminated, but only 1.6% of the contamination appeared to be internal (10). In the late 1980's, Dwinell (unpublished) isolated the pitch canker fungus from seeds of Monterey pine in areas where the disease was prevalent, but not from seeds collected at locations in which the disease was absent.

External seed contamination could possibly be eradicated by appropriate seed treatments. Soaking shortleaf pine seeds in a 30% solution of hydrogen peroxide has shown promise (10). At present, the relationship between the surface contamination of pine seeds by *F. subglutinans* f. sp. *pini* and pre- and post-emergence damping-off as well as disease in older seedlings has not been fully elucidated. Seed treatments represent the best insurance to prevent potential seedling losses.

Summary

Since pitch canker was first described in 1946, the parameters of the disease have been in a constant state of change. The impact that the pitch canker fungus could have on pine forests was fully recognized by phytopathologists in 1974 when the pitch canker disease became epidemic in the southeastern United States on planted slash and loblolly pines. In the past two decades, pitch canker fungus has evolved from being a regional pathogen, to one of national and international importance. Since 1986, pitch canker fungus has seriously damaged Monterey pine in coastal central California and has all the characteristics of an introduced pest. Pitch canker has been reported on pines in Haiti, Japan and Mexico. In South Africa, the pathogen induces a root rot of containerized *Pinus patula* seedlings. Although the major damage from this disease typically is the infection of woody vegetative structures, the pitch canker fungus also infects reproductive structures causing mortality of female flowers and mature cones, and deteriorates seeds of several pine species.

References

1. Adams, D. 1989. Incidence of pine pitch canker in California, 1988-1989. California Department of Forestry and Fire Protection, Sacramento, CA. 25 pp.
2. Barnard, P.E. and Blakeslee, G.M. 1980. Pitch canker of slash pine seedlings: a new disease in forest nurseries. Plant Dis. 64:695-696.
3. Barrow-Broaddus, Jane. 1987. Pitch canker. Pages 42-49 in: Sutherland, J.R., Miller, T., and Quinard, R.S. (eds.). Cone and seed diseases on North American conifers. North American Forestry Commission Publication No. 1. Victoria, British Columbia.
4. Barrows-Broaddus, J.B. and Dwinell, L.D. 1985. Branch dieback and cone and seed infection caused by *Fusarium moniliforme* var. *subglutinans* in a loblolly pine seed orchard in South Carolina. Phytopathology 75:1104-1108.
5. Blakeslee, G.M., Oak, S.W., Gregory, W., and Moses, C.S. 1978. Natural association of *Fusarium moniliforme* var. *subglutinans* with *Pissodes nemorensis*. (Abstract) Phytopathol. News 12:208.
6. Carey, W.A. and W.D. Kelley. 1994. First report of *Fusarium subglutinans* as a cause of late-season mortality in longleaf pine nurseries. Plant Dis. 78:754.
7. Correll, J.C., Gordon, T.R., and McCain, A.H. 1992. Genetic diversity in California and Florida populations of the pitch canker fungus *Fusarium subglutinans* f. sp. *pini*. Phytopathology 82:415-420.
8. Correll, J.C., Gordon, T.R., McCain, A.H., Fox, J.W., Koehler, C.S., Wood, D.L., and Schultz. 1991. Pitch canker disease in California: Pathogenicity, distribution, and canker development on Monterey pine (*Pinus radiata*). Plant Dis. 75:676-682.
9. Dwinell, L.D. and Barrows-Broaddus, J.B. 1985. Infection of fusiform rust galls on slash and loblolly pines by the pitch canker fungus *Fusarium moniliforme* var. *subglutinans*. Pages 239-250 in: Barrows-Broaddus, J.B. and Powers, H.R. (eds.). Proc. of the Rust of Hard Pines Working Party Conference S 2.06-2.10. IUFRO and USDA Forest Service Southeastern For. Expt. Sta., October 1-3, 1994, Athens, Georgia.
10. Dwinell, L.D. and Fraedrich, S.W. 1997. Recovery of *Fusarium subglutinans* f. sp. *pini* from shortleaf pine cones and seeds. Pages 42-47 in: James, R. (ed.). Proc. of the Diseases and Insects in Forest Nurseries IUFRO Working Party Conference S 7.03-04, May 19-24, 1996, Gainesville, Florida.
11. Dwinell, L.D. and Phelps, W.R. 1977. Pitch canker of slash pine in Florida. J. For.: 75:488-489.
12. Dwinell, L.D., Barrows-Broaddus, J., and Kuhlman, E.G. 1985. Pitch canker: a disease complex of southern pines. Plant Dis. 69:270-276.
13. Fox, J.W., Wood, D.L., Koehler, C.S., and O'Keefe, S.T. 1991. Engraver beetles (Scolyytidae: *Ips* species) as vectors of the pitch canker fungus, *Fusarium subglutinans*. Can. Ent. 123:1355-1367.
14. Fraedrich, S.W. and Dwinell, L.D. 1997. Mortality of longleaf pine seedlings caused by *Fusarium subglutinans* and an evaluation of potential inoculum sources. Pages 48-54 in: James, R. (ed.). Proc. of the Diseases and Insects in Forest Nurseries IUFRO Working Party Conference S 7.03-04, May 19-24, 1996, Gainesville, Florida.
15. Hepting, G.H. 1971. Diseases of forest and shade trees of the United States. USDA Forest Serv. Agric. Handb. 386. 658 pp.

16. Hepting, H.H. and Roth, E.R. 1946. Pitch canker, a new disease of southern pines. J. For. 44:742-744.
17. Hepting, G.H. and Roth, E.R. 1953. Host relations and spread of the pine pitch canker disease. (Abstract). Phytopathology 43:475.
18. Kuhlman, E.G., Dianis, S.D., and Smith, T.K. 1982. Epidemiology of pitch canker disease in a loblolly pine seed orchard. Phytopathology 72:121-126.
19. Kuhlman, E.G., Dwinell, L.D., and Nelson, P.E., and Booth, C. 1978. Characterization of the *Fusarium* causing pitch canker of southern pines. Mycologia 70:1131-1143.
20. Matthews, F.R. 1962. Pitch canker-tip moth damage association on slash pine seedlings. J. For. 60:825-826.
21. McCain, A.H., Koehler, C.S., and Tjosvold, S.A. 1987. Pitch canker threatens California pines. California Agriculture 41:22-23.
22. Miller, T. and Bramlett, D.L. 1979. Damage of reproductive structures of slash pine by two seed-borne pathogens: *Diplodia gossypina* and *Fusarium moniliforme* var. *subglutinans*. Pages 347-355 in: Bonner, F. (ed.). Proc.: A Symposium on Flowering and Seed Development in Trees. U.S. Dep. Agric. Southern For. Exp. Sta.
23. Muramoto, M. and Dwinell, L.D. 1990. Pitch canker of *Pinus luchuensis* in Japan. Plant Dis. 74:530.
24. Muramoto, M., Minamihashi, H., and Kobayashi, T. 1988. Occurrence of resiniterous damage on *Pinus lunchuensis* Mayr.: symptoms and analysis of the damage. Trans. 99th Annual Meeting Japanese Forestry Society. pp. 513-514.
25. Perry, Jr., J.P. 1991. The pines of Mexico and Central America. Timber Press, Inc., Portland, Oregon. 231 pp.
26. Santos, J.J.G. 1995. El cancro resinoso causado por *Fusarium subglutinans* (Wollenw. y Reink.) Nelson, Tousson y Marasas, una nueva enfermedad de *Pinus* spp. en Mexico. Master's of Science Thesis, Universidad Autonoma Chipingo, Chapingo, Mexico. 97 pp.
27. Snyder, W.C., Toole, E.R., and Hepting, G.H. 1949. Fusaria associated with mimosa wilt, and pine pitch canker. J. Agric. Res. 78:365-382.
28. Storer, A.J., Gordon, T.R., Dallara, P.L., and Wood, D.L. 1994. Pitch canker kills pines, spreads to new species and regions. California Agriculture 48:9-13.
29. Viljoen, A., Wingfield, M.J., Marasa, W.F.O. 1995. First report of *Fusarium subglutinans* f. sp. *pini* on pine seedlings in South Africa. Plant Dis. 78:309-312.
30. Viljoen, A., Marasas, W.F.O., Wingfield, M.J. and Viljoen, C.D. 1997. Characterization of *Fusarium subglutinans* f. sp. *pini* causing root disease of *Pinus patula* seedlings in South Africa. Mycological research 101:437-445.