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An Annotated Bibliography of Invasive Tree Pathogens *Sirococcus clavigignenti-juglandacearum, Phytophthora alni,* and *Phytophthora quercina* and of Regulatory Policy and Management Practices for Invasive Species

T. M. Seeland, M.E. Ostry, R. Venette, and J. Juzwik

North Central Research Station
U.S. Department of Agriculture - Forest Service
1992 Folwell Avenue
Saint Paul, Minnesota 55108
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www.ncrs.fs.fed.us

FOREWORD

The USDA Forest Service has identified invasive species as significant threats to forest and rangeland ecosystems (www.fs.fed.us). This bibliography is organized around the four program elements defined in the USDA Forest Service's National Strategy and Implementation Plan for Invasive Species Management (United States Department of Agriculture 2004). It is intended as a tool for researchers, policymakers, and land managers working in invasive species management to expediently locate key papers on the topics addressed. The four program elements are: prevention, early detection and rapid response, control and management, and rehabilitation and restoration. Three species are included in the database: *Sirococcus clavigignenti-juglandacearum* Nair, Kostichka & Kuntz, *Phytophthora alni* Brasier & S. A. Kirk, and *Phytophthora quercina* T. Jung. *S. clavigignenti-juglandacearum* is the causal agent of butternut canker on butternut (*Juglans cinerea*) and is widespread throughout the butternut range in North America. Management tools and resistant butternut varieties are still being developed. *P. alni* has been found on alders in Europe and in many cases is associated with alder mortality, but it has not yet been detected in North America. *P. quercina* is also widespread in Europe and is implicated as a factor in oak decline. Both *Phytophthora* species represent a threat to North American trees because of the widespread distribution of their hosts on the continent and their ability to be spread via soil. Articles in this bibliography were selected because they address one or more of the program elements; they are not inclusive of all literature available. Also included are articles addressing regulatory policy and management practices for invasive species in general. The literature was compiled from scientific journals, books, conference proceedings, and government reports and is current through August 2005. This bibliography includes a list of keywords associated with the program elements that can be used to search the database.

1. **Allen, E.A.; Humble, L.M. 2002.** Nonindigenous species introductions: a threat to Canada's forests and forest economy. Canadian Journal of Plant Pathology. 24: 103-110.

The introduction and spread of invasive species is the focus of this paper. Pathways of introduction for invasive species, such as solid wood packing materials, are described. International and regional cooperation to regulate the spread of invasive species is promoted. How to determine which introduced organisms will become pests using species complexes associated with indigenous tree species is discussed.

2. **Balci, Y.; Halmschlager, E. 2003a.** Incidence of *Phytophthora* species in oak forests in Austria and their possible involvement in oak decline. Forest Pathology. 33: 157-174.

Thirty-five sites in Austria were surveyed to determine distribution of *Phytophthora* species and their effect on crown deterioration. *P. quercina* was found at 11 sites and was the *Phytophthora* species recovered most frequently. *P. quercina* was found on a number of oak species and in a broad range of environmental conditions. Although there was no significant correlation between *P. quercina* and crown deterioration, a correlation was found between crown deterioration and *Phytophthora* species in general.

3. **Balci, Y.; Halmschlager, E. 2003b.** *Phytophthora* species in oak ecosystems in Turkey and their association with declining oak trees. Plant Pathology. 52: 694-702.

Surveys conducted in Turkey for *Phytophthora* species found *P. quercina* was the most frequently recovered *Phytophthora* from soil samples. *P. quercina* was also found in the largest geographical and pH ranges and was 1.9 times more likely to be isolated from trees with crown damage. *Phytophthora* species in general were 1.6 times more likely to be isolated from samples of trees with crown damage.

4. **Barzanti, G.P.; Capretti, P.; Ragazzi, A. 2001.** Characteristics of some *Phytophthora* species isolated from oak forest soils in central and northern Italy. Phytopathologia Mediterranea. 40: 149-156.

Morphological characteristics are described for four *Phytophthora* species found in oak forests in Italy. Isolations were taken from both healthy and declining trees. Growth rates and host associations of *P. citricola, P. megasperma*, *P. quercina*, and *P. syringae* are compared to reports from other countries.

5. **Beardmore, T.; Forbes, K.; Loo, J.; Simpson, D. 2004.** Ex situ conservation strategy for butternut (*Juglans cinerea*). In: Forest genetics and tree breeding in the age of genomics: progress and future: Proceedings, IUFRO joint conference of Division 2; 2004 November 1-5; Charleston, SC. [Asheville, NC]: North Carolina State University: 189-193. [Available online: http://www.ncsu.edu/feop/iufro_genetics2004/proceedings.pdf].

A cryopreservation technique for germplasm conservation of butternut axes is described. Germination of cryopreserved axes decreased after 24 hours but germination rates 1.5 and 6 years later were comparable to the 24 hour germination rates.

6. **Beardmore, T.; Vong, W. 1998.** Role of the cotyledonary tissue in improving low and ultralow temperature tolerance of butternut (*Juglans cinerea*) embryonic axes. Canadian Journal of Forest Research. 28: 903-910.

This article compares low and ultralow temperatures for storing butternut embryonic axes for use in ex situ conservation. Embryonic axes, with and without cotyledons, were subjected to temperatures as low as -196^{o} C. Viability of the axes after storage was directly related to the moisture content before low or ultralow temperature storage.

7. **Brasier, C.M.; Cooke, D.E.L.; Duncan, J.M. 1999.** Origin of a new *Phytophthora* pathogen through interspecific hybridization. Proceedings of the National Academy of Sciences USA. 96: 5878-5883

Alder *Phytophthora* isolates collected from Germany, The Netherlands, Sweden, and the United Kingdom showed highly variable differences in phenotypes. These differences as well as amplified fragment length polymorphisms (AFLP) and cytological results are outlined here. Evidence suggests the alder *Phytophthoras* are a hybrid complex.

8. **Brasier, C.M.; Kirk, S.A.; Delcan, J.; *et al.* 2004.** *Phytophthora alni* sp. nov. and its variants: designation of emerging heteroploid hybrid pathogens spreading on *Alnus* trees. Mycological Research. 108: 1172-1184.

A new alder *Phytophthora*, *Phytophthora alni* subsp. *alni*, is described here. Two other closely related *Phytophthora* species, *P. alni* subsp. *uniformis* and *P. alni* subsp. *multiformis,* are also described here. Naming protocols for emerging hybrid fungal species are discussed.

9. **Brasier, C.M.; Rose, J.; Gibbs, J.N. 1995.** An unusual *Phytophthora* associated with widespread alder mortality in Britain. Plant Pathology. 44: 999-1007.

Alder *Phytophthora* cultures isolated from diseased trees and soil collected from around diseased trees in south Britain are examined for morphological characteristics. Sporangia, gametangia, and growth rates are measured. Similarities to *P. cambivora* are discussed.

10. **Campbell, F.T. 2001.** The science of risk assessment for phytosanitary regulation and the impact of changing trade regulations. BioScience. 51: 148-153.

This article examines the policies governing prevention programs for exotic pests and the implementation of those programs. There is also some discussion on the sanitary and phytosanitary measures (SPS) agreement and how it can be improved. The USDA's Animal and Plant Health Inspection Service (APHIS) can work within the restrictions of the SPS agreement while still promoting zero risk for pest introductions.

11. **Campbell, F.T.; Schlarbaum, S.E. 1994.** Fading forests: North American trees and the threat of exotic pests. New York, NY: Natural Resources Defense Council. 47 p.

Case histories of pests introduced to North America are used to show the ecological and economical impact of exotic pests. Potential pest introductions are discussed and suggestions are made for cooperation across agencies to create a comprehensive pest management program at the national level.

12. **Campbell, F.T.; Schlarbaum, S.E. 2002.** Fading forests II: trading away North America's natural heritage. Knoxville, TN: Healing Stones Foundation in cooperation with the American Lands Alliance and the University of Tennessee. n.p.

This report summarizes the past performance of the USDA's Animal and Plant Health Inspection Service (APHIS) and some of the regulatory issues hampering its success. The authors suggest changes that can be made now to reduce the threat of exotic/invasive pests entering through our ports. These suggestions include changes in laws, funding, and trade policy.

13. **Clinton, W.J. 1999.** Executive Order 13112, Invasive species. Federal Register. 64: 6183-6186.

This Executive order includes definitions of terms used, duties of any Federal agencies that affect invasive species, establishment of an invasive species council and its duties, and commissioning of an invasive species management plan.

14. **Committee on the Scientific Basis for Predicting the Invasive Potential of Nonindigenous Plants and Plant Pests in the United States. 2002.** Predicting invasions of nonindigenous plants and plant pests. Washington, DC: National Academy Press. 194 p.

The committee that authored this book was established by the National Research Council's Board on Agriculture and Natural Resources (BANR). The goal of this report was to look at the invasion process and how a pest could be introduced, establish itself, and spread. Economic impacts are also included.

15. **Cooke, D.E.L.; Jung, T.; Williams, N.A.; *et al*. 2005.** Genetic diversity of European populations of the oak fine-root pathogen *Phytophthora quercina*. Forest Pathology. 35: 57-70.

Amplified fragment length polymorphism (AFLP) markers are used to determine the genetic diversity of *Phytophthora quercina* in several European countries. Diversity is looked at geographically and by host. Discussion about the origin of *P. quercina* based on its genetic diversity is included.

16. **Cooke, D.E.L.; Jung, T.; Williams, N.A.; *et al*. 1999.** Molecular evidence supports *Phytophthora quercina* as a distinct species. Mycological Research. 103: 799-804.

Molecular tools are used to verify *Phytophthora quercina* as a distinct species. Random amplified polymorphic DNA (RAPD) markers are used to obtain intraspecies similarities. Restriction digests had unique results when run on *P. quercina* isolates. The ITS1, ITS2, and 5.8s subunit were all sequenced, and the resulting dendograms are published here.

17. **Corn, M.L.; Buck, E.H.; Rawson, J.; Fischer, E. 1999.** Harmful non-native species: issues for Congress. Rep. RL30123. [Washington, DC]: Congressional Research Service, The Library of Congress: 1-66.

This report summarizes the environmental and economic effect of invasive pests and legislation and laws surrounding this issue. An overview of pathways and possible prevention and control methods is given. Also included is a list of agencies and their contribution to the invasive species effort. Finally, brief descriptions of selected invasive species are given.

18. **Cummings Carlson, J.; Kopitzke, D. 1997.** Wisconsin's increasingly rare butternuts. Woodland Management. 18(3): 9-14.

This article describes the butternut tree and its range. Tips for regeneration are included as well as criteria for butternut trees that can be included in the resistance program implemented by the USDA Forest Service.

19. **De Merlier, D.; Chandelier, A.; Debruxelles, N.; *et al*. 2005.** Characterization of alder *Phytophthora* isolates from Wallonia and development of SCAR primers for their specific detection. Journal of Phytopathology. 153: 99-107.

Species-specific primers developed for alder *Phytophthora* are able to detect *P. alni* subsp. *alni* and *P. alni* subsp. *uniformis,* but not *P. alni* subsp. *multiformis.* These primers work on DNA extracted from mycelium or diseased tissue. Phenotypic traits and pathogenicity are also compared among isolates.

20. **Fjellstrom, R.G.; Parfitt, D.E. 1994.** Walnut (*Juglans* spp.) genetic diversity determined by restriction fragment length polymorphisms. Genome. 37: 690-700.

Restriction fragment length polymorphisms (RFLPs) are used in this study to determine genetic diversity among *Juglans* species. Butternut was shown to have little genetic diversity in most of the populations studied. However, a population from North Carolina had a high level of genetic diversity. More germplasm needs to be collected from butternut to increase the diversity of existing germplasm collections. The RFLP results were also used in an unweighted pair group method with arithmatic mean (UPGMA) cluster analysis to generate a tree showing taxonomic associations.

21. **Fleguel, V.R. 1996.** A literature review of butternut and the butternut canker. Kemptville, ON: Eastern Ontario Model Forest=Forêt modèle de l'est de l'Ontario. 32 p.

This literature review touches on all aspects of past work with butternut and butternut canker. Topics include growth characteristics of butternut, symptoms and characteristics of butternut canker, management practice, and germplasm conservation strategies.

22. **Forest Gene Conservation. [n.d.].** A landowner's guide to butternut canker in Ontario. Kemptville, ON: Forest Gene Conservation Association. 6 p.

This educational brochure describes how to identify butternut and symptoms of butternut canker. It also discusses woodlot management and where to report a disease-free butternut.

23. **Foster, J.A. 1988.** Regulatory actions to exclude pests during the international exchange of plant germplasm. HortScience. 23: 60-66.

This article looks at pests that could be imported on germplasm and regulatory actions that can be taken to reduce the risk.

24. **Furnier, G.R.; Stolz, A.M.; Mustaphi, R.M.; Ostry, M.E. 1999.** Genetic evidence that butternut canker was recently introduced into North America. Canadian Journal of Botany. 77: 783-785.

North American isolates of *Sirococcus clavigignenti-juglandacearum* were collected from cankers on butternut branches. These isolates were collected across the North American range for butternut with the majority of the samples coming from Wisconsin and New York. Randomly amplified polymorphic DNA (RAPD) markers were used to discover that the *S. clavigignenti-juglandacearum* population in North America is monomorphic, which supports a single introduction event theory. This also means the pathogen is unlikely to be able to overcome host resistance.

25. **Gibbs, J.; van Dijk, C.; Webber, J., eds. 2003.** Phytophthora disease of alder in Europe. Bulletin 126. Edinburgh: Forestry Commission. 81 p.

This bulletin addresses the history of the alder *Phytophthoras* and the current status of the disease-causing pathogen and its spread throughout Europe. Management issues and future research opportunities are also discussed.

26. **Gibbs, J.N. 1995.** *Phytophthora* root disease of alder in Britain. EPPO Bulletin. 25: 661-664.

This article takes an early look at the root disease caused by *Phytophthora* in alder. Results of a survey for diseased trees are introduced.

27. **Gibbs, J.N.; Lipscombe, M.A.; Peace, A.J. 1999.** The impact of *Phytophthora* disease on riparian populations of common alder (*Alnus glutinosa*) in southern Britain. European Journal of Forest Pathology. 29: 39-50.

Surveys for crown disease or death of alders were done in southern England and eastern Wales from 1994 to 1996. Besides data collected on trees affected by the disease, there were two notable finds. First, more disease symptoms were found on alders growing within 1 m of a riverbank than on trees further away. Second, there was a 45 percent increase in crown symptoms and a 100 percent increase in tree death from 1994 to 1996.

28. **Halik, S.; Bergdahl, D.R. 2002.** Potential beetle vectors of *Sirococcus clavigignenti-juglandacearum* on butternut. Plant Disease. 86: 521-527.

Researchers identify species of beetles associated with butternut trees infected with the pathogen *Sirococcus clavigignenti-juglandacearum*. Beetles associated with healthy crowns of butternut are also found. Further research is needed to determine which species are likely to successfully introduce the pathogen to healthy trees.

29. **Hansen, E.; Delatour, C. 1999.** *Phytophthora* species in oak forests of north-east France. Annals of Forest Science. 56: 539-547.

Surveys conducted in two forests in northeastern France looked for correlation between *Phytophthora* and environmental stress on the incidence of oak decline. *P. quercina* was found in a few places, but there was no link between the presence of *P. quercina* and oak decline. Also, no correlation was found between oak decline and the presence or absence of *Phytophthora* in general in the areas surveyed.

30. **Hopkin, A.; Innes, L.; Harrison, K. 2000.** Distribution of butternut canker (*Sirococcus clavigignenti-juglandacearum*) in eastern Canada. Canadian Plant Disease Survey. 81: 154-157.

This survey investigates the natural range of butternut in eastern Canada. Trees that were symptomatic or dead were sampled for the presence of *Sirococcus clavigignenti-juglandacearum*. The article includes a map of butternut canker sites found during this survey.

31. **Jacobs, K.A.; Berg, L.C. 2000.** Inhibition of fungal pathogens of woody plants by the plant growth regulator paclobutrazol. Pest Management Science. 56: 407-412.

This research tested the effects of paclobutrazol (PBZ) on eight fungal pathogens of woody plants. In vitro studies measured the inhibitory effects of PBZ on mycelial growth and spore germination. *Sirococcus clavigignenti-juglandacearum*, the causal agent of butternut canker, was included in this study. *S. clavigignenti-juglandacearum* was especially sensitive to PBZ.

32. **Jönsson, U. 2003.** *Phytophthora* species and oak decline—can a weak competitor cause significant root damage in a nonsterilized acidic forest soil? New Phytologist. 162: 211-222.

The effect of *Phytophthora quercina* and *P. cactorum* on the fine and coarse roots of *Quercus robur* and the correlation to nutrient levels in leaves is observed. After 6 months, loss of fine roots and lesions on coarse roots were noted, but nutrient levels in leaves were not significantly affected.

33. **Jönsson, U.; Lundberg, L.; Sonesson, K.; Jung, T. 2003.** First records of soilborne *Phytophthora* species in Swedish oak forests. Forest Pathology. 33: 175-179.

A survey of southern Sweden for *Phytophthora* species associated with oak is presented. In all, 32 oak stands were surveyed. Of the 32 stands, 27 had trees with 20-65 percent crown defoliation and 5 had trees with less than 20 percent crown defoliation. Three *Phytophthora* species were recovered. *P. quercina* was found in 35 percent of the samples, and *P. cambivora* and *P. cactorum* were each found in 2 percent of the samples. No *Phytophthora* species were found in the healthy stands.

34. **Jung, T.; Blaschke, H.; Neumann, P. 1996.** Isolation, identification and pathogenicity of *Phytophthora* species from declining oak stands. European Journal of Forest Pathology. 26: 253-272.

This research investigates the effect of *Phytophthora* species on oak decline in Europe. Species identification was done by colony growth patterns and morphology. Pathogenicity and toxigenicity tests were also run. Three unknown *Phytophthoras* were found, one of which was later named *P. quercina*.

35. **Jung, T.; Blaschke, H.; Oßwald, W. 2000.** Involvement of soilborne *Phytophthora* species in Central European oak decline and the effect of site factors on the disease. Plant Pathology. 49: 706-718.

This survey shows the connection between the condition of fine roots and condition of the crown in oak species. The condition of the fine roots is then correlated to the presence of *Phytophthora* species, type of soil, and pH level.

36. **Jung, T.; Blaschke, M. 2004.** *Phytophthora* root and collar rot of alders in Bavaria: distribution, modes of spread and possible management strategies. Plant Pathology. 53: 197-208.

Between January 2000 and May 2002, surveys were conducted on forest and riparian alder stands and three forest nurseries in Bavaria. *Phytophthora* was recovered from both forest and riparian alder stands. Alder *Phytophthora* was not likely to be recovered from nursery alders started from seed but was found in alders from commercial nurseries. Pathways of infection and management strategies are discussed.

37. **Jung, T.; Cooke, D.E.L.; Blaschke, H.; *et al*. 1999.** *Phytophthora quercina* sp. nov., causing root rot of European oaks. Mycological Research. 103: 785-798.

This article describes the new *Phytophthora* species, *P. quercina*.

38. **Kahn, R.P. 1979.** A concept of pest risk analysis. EPPO Bulletin. 9: 119-130.

Components used to create a pest risk analysis based on the known biology of the organism are presented. Non-biological components and how they would be included in a pest risk analysis are discussed. Uses for a pest risk analysis curve are described.

39. **Kahn, R.P. 1985.** Plant quarantine and international shipment of tissue culture plants. In: Zimmerman, R.H., *et al*., eds. Conference on tissue culture as a plant production system for horticultural crops; 1985 October 20-23; Beltsville, MD. Dordrecht, The Netherlands: Kluwer Academic Publishers: 147-163.

This article looks at the risks of importing tissue culture from other countries. Typical pathways of introduction for exotic pests are discussed as a point of reference for tissue culture importation issues. Finally, specifics about importing tissue cultures and safeguards associated with them are presented.

40. **Kahn, R.P. 1989.** Plant protection and quarantine. Boca Raton, FL: CRC Press, Inc. 3 volumes.

This three-volume set addresses plant protection and quarantine issues. Volume I discusses biological characteristics of 12 different groups of pests that include pathogens, insects, and weeds. Content of a pest risk assessment and evaluation of organisms to determine the need to quarantine is included. Volume II analyzes various pathogens and the epidemiology of

the diseases they cause. Diagnostic problems of various pests and difficulties of detection are discussed. Volume III explores topics specific to plant protection and quarantine workers such as international pest databases, quarantines, plant quarantine training, and regulatory treatments among others.

41. **Kahn, R.P. 1991.** Exclusion as a plant disease control strategy. Annual Review of Phytopathology. 29: 219-246.

    This article discusses plant quarantine as a regulatory strategy for disease control. Topics included are factors affecting exclusion policies such as economics, biology, policy, negative image of quarantines, and research needed to support quarantine decisions.

42. **Katovich, S.A.; Ostry, M.E. 1998.** Insects associated with butternut and butternut canker in Minnesota and Wisconsin. The Great Lakes Entomologist. 31: 97-108.

    Insects were collected in Wisconsin and Minnesota from diseased, damaged, and healthy butternut trees in 1995 and 1996. In a few cases, attempts were made to isolate *Sirococcus clavigignenti-juglandacearum* from the insects collected.

43. **Ledig, F.T. 1986.** Conservation strategies for forest gene resources. Forest Ecology and Management. 14: 77-90.

    Special considerations needed for gene conservation in forests are presented. In situ vs. ex situ gene conservation and social and political aspects affecting conservation decisions are presented.

44. **Ledig, F.T.; Vargas-Hernández, J.J.; Johnsen, K.H. 1998.** The conservation of forest genetic resources. Journal of Forestry. 96: 32-41.

    Case histories of three forest trees are presented. The case histories are used to support ex situ gene conservation in addition to in situ conservation. The article urges a national germplasm conservation effort.

45. **Liebhold, A.M.; MacDonald, W.L.; Bergdahl, D.; Mastro, V.C. 1995.** Invasion by exotic forest pests: a threat to forest ecosystems. Forest Science Monograph. 30: 1-49.

    Pathways through which exotic pests enter and the environment necessary for them to establish and then spread are discussed. Included are nine case histories.

46. **Loo, J. 1998.** Development of conservation strategies for New Brunswick trees at risk. In: Proceedings, Northeastern Forest Pest Council annual meeting 1998. Fredericton, New Brunswick, Canada: 30-35.

    The author outlines steps necessary to conserve genetic diversity in forest trees. These steps include (1) determining if a species should be included in a conservation effort, (2) prioritizing species that need help using a risk assessment approach, and (3) determining the range of help needed at the forest level and at the germplasm level.

47. **Loo, J. 2004.** Conservation of forest genetic resources: national and international perspectives. In: Forest genetics and tree breeding in the age of genomics: progress and future: proceedings, IUFRO joint conference of Division 2; 2004 November 1-5; Charleston, SC. [Asheville, NC]: North Carolina State University: 89-95. [Available online: http://www.ncsu.edu/feop/iufro_genetics2004/proceedings.pdf].

    This article outlines the need for a coordinated forest gene conservation program.

48. **Mack, R.N.; Simberloff, D.; Lonsdale, W.M.; *et al.* 2000.** Biotic invasions: causes, epidemiology, global consequences and control. Issues in Ecology. 5: 1-20.

    This article outlines how an exotic invades, what makes a good invader, and what types of environments are vulnerable to an invasion. It then discusses the impact an invasion has on the environment and ways to prevent or control those invasions.

49. **Mathys, G. 1975.** Thoughts on quarantine problems. EPPO Bulletin. 5: 55-64.

    This article encourages organizations involved with pest quarantine to look at bio-regional areas rather than individual countries when establishing quarantines. Models developed by a U.S. task force are used to rank the threat of specific exotic pests. More

scientific understanding of the biology of the pests is needed to produce an accurate model for predicting the risk of an exotic pest.

50. **Mathys, G.; Baker, E.A. 1980.** An appraisal of the effectiveness of quarantines. Annual Review of Phytopathology. 18: 85-101.

This article reviews the history of plant quarantine and issues surrounding identification of organisms for quarantine. Types of quarantine measures and ways to evaluate the effectiveness of quarantines are discussed.

51. **McGregor, R.C. 1973.** The emigrant pests. Berkeley, CA: Import Inspection Task Force. 167 p.

This report is written by the Chairman of the Import Inspection Task Force and is addressed to the Administrator of the Animal and Plant Health Inspection Service (APHIS). Topics include pathways, risks, top ranked exotic pests, programs for foreign and U.S. protection, assessments of quarantine effects, and recommendations for improvements in the current system.

52. **McIlwrick, K.; Wetzel, S.; Beardmore, T.; Forbes, K. 2000.** Ex situ conservation of American chestnut (*Castanea dentata* (Marsh.) Borkh.) and butternut (*Juglans cinerea* L.), a review. The Forestry Chronicle. 76: 765-774.

Genetic conservation efforts for American chestnut and butternut are reviewed. Criteria for maintaining genetic diversity when setting up gene conservation programs are outlined. The authors stress a coordinated conservation program is needed for both in situ and ex situ collections.

53. **Millikan, D.F.; Stefan, S.J.; Rigert, K.S. 1990.** Selection and preservation of butternut, *Juglans cinerea* L. Annual Report of the Northern Nut Growers Association. 81: 22-25.

Butternut cultivars that have been selected for their nut and wood qualities are presented. These cultivars are being stored at the National Clonal Germplasm Repository in Corvallis, Oregon, for propagation material to be used for research and breeding.

54. **Morin, R.; Beaulieu, J.; Deslauriers, M.; *et al*. 2000.** Low genetic diversity at allozyme loci in *Juglans cinerea*. Canadian Journal of Botany. 78: 1238-1243.

This study looks at genetic diversity at allozyme loci in butternut trees with little or no symptoms of butternut canker. These trees were from populations at the northeastern limit of the butternut range in North America. Results show low genetic diversity in all the populations studied. Discussion includes the necessity for conservation of genetic resources.

55. **Nair, V.M.G. 1999.** Butternut canker—an international concern. In: Raychaudhuri, S.P.; Maramorosch, K., eds. Biotechnology and plant protection in forestry science. Enfield, NH: Science Publishers: 239-252.

This review of the butternut canker pathogen, *Sirococcus clavigignenti-juglandacearum*, includes symptoms, host range, and epidemiology. Photographs of cankers and progression of hyphae and cell damage are shown. Mechanisms of resistance in *Juglans* spp. are discussed.

56. **Nair, V.M.G.; Kostichka, C.J.; Kuntz, J.E. 1979.** *Sirococcus clavigignenti-juglandacearum*: an undescribed species causing canker on butternut. Mycologia. 71: 641-646.

A new species of *Sirococcus* is described. This species, *S. clavigignenti-juglandacearum*, is the first described on a deciduous tree.

57. **National Invasives Species Council. 2001.** Meeting the invasive species challenge: management plan. Washington, DC: National Invasives Species Council. 74 p.

This invasive species management plan prioritizes problem areas for managing invasive species. It also includes steps needed to address these problem areas.

58. **National Plant Board. 1999.** Safeguarding American plant resources: a stakeholder review of the APHIS-PPQ safeguarding system. Washington, DC: National Plant Board. 133 p.

The National Plant Board reviews Animal and Plant Health Inspection Service-Plant Protection and Quarantine (APHIS-PPQ) and their contribution to

safeguarding American plant resources from invasive plant pests. The recommendations given by the National Plant Board are designed to help APHIS-PPQ become an effective force in a global marketplace.

59. **Nechwatal, J.; Schlenzig, A.; Jung, T.; *et al*. 2001.** A combination of baiting and PCR techniques for the detection of *Phytophthora quercina* and *P. citricola* in soil samples from oak stands. Forest Pathology. 31: 85-97.

A detection system for *Phytophthora quercina* and *P. citricola* is developed using polymerase chain reaction (PCR) and baiting techniques. PCR detected *P. quercina* and *P. citricola* in leaves used as bait as well as in the water used in the bait tests. Species specific primers are used in both nested and semi nested PCR.

60. **Nicholls, T.H.; Kessler, K.J., Jr.; Kuntz, J.E. 1978.** How to identify butternut canker. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 6 p.

This educational brochure identifies characteristics of butternut and symptoms of butternut canker.

61. **Orchard, L.P. 1984.** Butternut canker: host range, disease resistance, seedling-disease reactions, and seed-borne transmission. Madison, WI: University of Wisconsin-Madison. 144 p. Ph.D. dissertation.

In this Ph.D. project the pathogenicity of *Sirococcus clavigignenti-juglandacearum* is tested on *Juglans* species and hybrids. During the course of this study, canker free butternut trees were inoculated to determine if they were resistant or escapes. A butternut seedling inoculation technique is introduced. Finally, to determine if the pathogen is seed borne, seeds are harvested from infected butternut trees, germinated, and then observed for canker formation.

62. **Orr, R.L.; Cohen, S.D.; Griffin, R.L. 1993.** Generic non-indigenous pest risk assessment process. Riverdale, MD: U.S. Department of Agriculture, Animal and Plant Health Inspection Service, Planning and Risk Analysis Systems, Policy and Program Development. 40 p.

This article describes a generic process for generating a non-indigenous pest risk assessment. Instructions are included for collecting and analyzing data relevant to a pest risk assessment. Appendices are included with mock forms and directions for calculating the input of the data collected. This process can be used to produce a quick assessment or a more detailed assessment.

63. **Oßwald, W.; Jung, T.; Nechwatal, J.; *et al*. 2001.** Significance of *Phytophthoras* and *Pythium* for oak, alder, and spruce decline. Journal of Forest Science. 47: 96-103.

Correlations between root parameters and crown transparency are made in this article. Soil pH below 3.5 is speculated to be a limiting factor for the presence of *Phytophthora* in soil samples.

64. **Ostry, M.E. 1997.** *Sirococcus clavigignenti-juglandacearum* on heartnut (*Juglans ailantifolia* var. *cordiformis*). Plant Disease. 81: 1461.

This report documents the first incidence of *Sirococcus clavigignenti-juglandacearum* found on heartnut (*Juglans ailantifolia* var. *cordiformis*) in Iowa.

65. **Ostry, M.E. 2001.** The need for butternut conservation. Annual Report of the Northern Nut Growers Association. 92: 11-15.

The current state of the butternut population is discussed. Dispersal of inoculum, range of disease spread, and conservation strategies for species at risk are outlined. Butternut clonal archives have been established with trees showing phenotypic resistance to *Sirococcus clavigignenti-juglandacearum*.

66. **Ostry, M.E.; Ellingson, B.; Seekins, D.; Ruckheim, W. 2002.** The need for silvicultural practices and collection of butternut germplasm for species conservation. In: Proceedings, 13th Central hardwood forest conference; 2002 April 1-3; Urbana, IL. Gen. Tech. Rep. NC-234. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station: 551-555.

Findings from butternut clonal archives are discussed as well as shortcomings of the program so far. Observations from 1993 to 2001 of a butternut regeneration study set up on the Nicolet National Forest are presented.

67. **Ostry, M.E.; Mielke, M.E.; Anderson, R.L. 1996.** How to identify butternut canker and manage butternut trees. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station: Northeastern Area State and Private Forestry: Region 8, State and Private Forestry. 8 p.

Epidemiology of butternut canker is described in this educational article. Forest management advice is given to aid in disease management. Planting strategies described for butternut are designed to minimize disease.

68. **Ostry, M.E.; Mielke, M.E.; Skilling, D.D. 1994.** Butternut-strategies for managing a threatened tree. Gen. Tech. Rep. NC-165. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station. 7 p.

This overview of butternut canker issues includes disease symptoms, natural regeneration of butternut using tree retention guidelines, strategies to maintain healthy butternut, and identification of trees that are candidates for resistance to butternut canker.

69. **Ostry, M.E.; Woeste, K. 2004.** Spread of butternut canker in North America, host range, evidence of resistance within butternut populations and conservation genetics. In: Black walnut in a new century: proceedings of the 6th Walnut Council research symposium; 2004 July 25-28; Lafayette, IN. Gen. Tech. Rep. NC-243. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station: 114-120.

The effect of butternut canker on butternut populations is reviewed. Reports of experiments to determine hosts for *Sirococcus clavigignenti-juglandacearum* as well as the probability of *S. clavigignenti-juglandacearum* overcoming resistance in butternut are presented. Finally, a discussion on the lack of genetic information for butternut and related species is included.

70. **Ostry, M.E.; Katovich, S.; Anderson, R.L. 1997.** First report of *Sirococcus clavigignenti-juglandacearum* on black walnut. Plant Disease. 81: 830.

This report documents the first incidence of *Sirococcus clavigignenti-juglandacearum* found on black walnut (*Juglans nigra*). The first finding was in North Carolina in 1985. Subsequent findings have been in Minnesota. In both cases, infected butternut trees were in close proximity to the infected black walnut.

71. **Palm, M.E. 1999.** Mycology and world trade: a view from the front line. Mycologia. 91: 1-12.

This article addresses the need for systematic knowledge of fungi to accurately identify native or nonindigenous fungi on imported materials.

72. **Palm, M.E. 2001.** Systematics and the impact of invasive fungi on agriculture in the United States. BioScience. 51: 141-147.

The importance of fungal systematics and biology to plant quarantine decisions is discussed.

73. **Palmer, M.A.; Ambrose, R.F.; Poff, N.L. 1997.** Ecological theory and community restoration ecology. Restoration Ecology. 5: 291-298.

Restoration ecology is discussed from the community point of view. Topics include the effects of biodiversity on restoration and the use of knowledge gained by theoretical work on natural succession as a means to hasten restoration. The relationship between ecological theory and restoration ecology is stressed.

74. **Rainville, A.; Innes, L.; Colas, F.; *et al*. 2001.** Butternut canker in Quebec: a 5-year history that led to seed treatments. Canadian Tree Improvement Association News Bulletin. 34: 14-16.

Observations of seed collections are made to determine if the pathogen *Sirococcus clavigignenti-juglandacearum* is seed borne on butternut. Techniques for pre-treating seeds to kill *S. clavigignenti-juglandacearum* before planting are explored. Treatments with hot water promise to be effective.

75. **Rajora, O.P.; Mosseler, A. 2001.** Challenges and opportunities for conservation of forest genetic resources. Euphytica. 118: 197-212.

This paper addresses maintenance of forest gene pools. Conservation strategies using in situ and ex situ techniques are discussed.

76. **Santini, A.; Barzanti, G.P.; Capretti, P. 2003.** Susceptibility of some mesophilic hardwoods to alder *Phytophthora*. Journal of Phytopathology. 151: 406-410.

The susceptibility of five hardwoods to the alder *Phytophthora* is tested here. The alder *Phytophthora* is able to infect alder species as well as other hardwoods although it does not kill other hardwoods as it does alder species. The article suggests more care should be taken in nurseries to prevent the spread of *Phytophthora* via other hardwood species.

77. **Schlarbaum, S.E.; Anderson, R.L.; Ostry, M.E.; *et al*. 2004.** An integrated approach for restoring butternut to eastern North American forests. In: Forest genetics and tree breeding in the age of genomics: progress and future: proceedings, IUFRO joint conference of Division 2; 2004 November 1-5; Charleston, SC. [Asheville, NC]: North Carolina State University: 156-158. [Available online: http://www.ncsu.edu/feop/iufro_genetics2004/proceedings.pdf].

These authors use an integrated approach to restore butternut. This approach includes using a GIS model to find areas suited to butternut restoration, resistance screening, and dendroecology to collect information about previous climate conditions and their effect on canker development.

78. **Schubert, R.; Bahnweg, G.; Nechwatal, J.; *et al*. 1999.** Detection and quantification of *Phytophthora* species which are associated with root-rot diseases in European deciduous forests by species-specific polymerase chain reaction. European Journal of Forest Pathology. 29: 169-188.

Species-specific primers are developed for *Phytophthora citricola*, *P. cambivora,* and *P. quercina*.

79. **Sinclair, W.A.; Lyon, H.H.; Johnson, W.T. 1987.** Sirococcus canker of butternut. In: Diseases of trees and shrubs. Ithaca, NY: Comstock Publishing Associates: 132-133.

Epidemiology of *Sirococcus clavigignenti-juglandacearum* on butternut is described. Descriptions of cankers, development of conidia, and spread of the disease are also discussed.

80. **Skilling, D.; Ostry, M.; Pijut, P. 1991.** The use of tissue culture to produce trees with resistance to canker diseases. In: Shoot diseases of conifers: proceedings of an international symposium; 1991 June 10-15; Garpenberg, Sweden. Uppsala, Sweden: Swedish University of Agricultural Sciences: 123-129.

This article describes the advantages of somaclonal variation in tissue culture and its application to breeding for disease resistance. A project to preserve butternut germplasm is discussed. Their threefold approach to preservation includes: grafting techniques to establish clonal lines of putatively resistant butternut; micropropagation techniques to develop those resistant lines; and development of a technique to inoculate in vitro to locate somaclonal variation that leads to disease resistance.

81. **Spaine, P.; McElreath, S.; Jolley, L. 2001.** Double-stranded RNA analysis of *Sirococcus* isolates from butternut cankers. Phytopathology. 91: S83.

This abstract explores the ability of dsRNA strains of *Sirococcus clavigignenti-juglandacearum* to heal butternut cankers. dsRNA positive isolates of *S. clavigignenti-juglandacearum* have been collected from butternut cankers at sites in North Carolina and Alabama.

82. **Spears, J.F. 1974.** A review of Federal domestic plant quarantines. Hyattsville, MD: U.S. Department of Agriculture. 95 p.

Author reviews the Federal plant quarantine policy and recommendations for improvement.

83. **Stefan, S.J.; Warmund, M.R.; Shaffer, W.H., Jr.; Millikan, D.F. 1984.** Propagation of butternut, *Juglans cinerea* L., by the Beineke side bud graft. Annual Report of the Northern Nut Growers Association. 75: 76-80.

The Beineke side bud graft technique is tested here for propagation of butternut. This method had an overall success rate of 52 percent on the 18 cultivars tested.

84. **Stewart, J.E.; Halik, S.; Bergdahl, D.R. 2004.** Viability of *Sirococcus clavigignenti-juglandacearum* conidia on exoskeletons of three coleopteran species. Plant Disease. 88: 1085-1091.

Three species of *Coleoptera* were examined for *Sirococcus clavigignenti-juglandacearum* conidia to determine their potential as a vector for this pathogen. Conidia were harvested from artificially inoculated beetles and tested for viability at intervals up to 16 days after inoculation. Further research is needed to determine if these species are attracted to healthy butternut trees and what they contribute to the disease cycle.

85. **Streito, J.-C.; Legrand, P.H.; Tabary, F.; Jarnouen De Villartay, G. 2002.** *Phytophthora* disease of alder (*Alnus glutinosa*) in France: investigations between 1995 and 1999. Forest Pathology. 32: 179-191.

Alder decline in France was surveyed between 1995 and 1999. Information presented includes region and site characteristics. Symptoms are noted as well as types of fungi isolated from diseased sites.

86. **Streito, J.-C.; Gibbs, J.N. 1999.** Alder phytophthora in France and the United Kingdom: symptoms, isolation methods, distribution and damage. In: Hanson, E.M.; Sutton, W., eds. First International meeting on *Phytophthoras* in forest and wildland ecosystems; 1999 August 30-September 3; Grants Pass, OR. Corvallis, OR: Oregon State University, Forest Research Laboratory. 152 p.

This is an overview of the alder *Phytophthora* disease in France and the United Kingdom. Symptoms, disease distribution, and isolation techniques are discussed.

87. **Tisserat, N.A.; Kuntz, J.E. 1982.** Epidemiology of butternut canker. In: Black walnut for the future. Gen. Tech. Rep. NC-74. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Forest Experiment Station: 18-22.

Research determined that spores could be dispersed up to 30 m via rain splash. New cankers from *Sirococcus clavigignenti-juglandacearum* can form on infected trees from spores in stem runoff. Cankers develop rapidly in the spring after fall or late summer infections. Infected trees, live or dead, are a source of inoculum and should be removed.

88. **Tkacz, B.M. 2002.** Pest risks associated with importing wood to the United States. Canadian Journal of Plant Pathology. 24: 111-116.

This article is an overview of the pest risk assessment process used to determine pest threats associated with wood imports. Summaries of individual pest risk assessments (IPRAs) previously completed and their effect on import regulations are included.

89. **U.S. Congress Office of Technology Assessment. 1993.** Harmful non-indigenous species in the United States. OTA-F-565. Washington, DC: U.S. Government Printing Office. 391 p.

The Office of Technology Assessment presents the background of the invasives issue as well as policy options on select topics. Also included are discussions about pathways and consequences of invasive introductions, management issues, and Federal and State approaches to management.

90. **U.S. Department of Agriculture, Forest Service. 2004.** National strategy and implementation plan for invasive species management. Washington, DC: U.S. Department of Agriculture, Forest Service. 16 p.

This publication outlines priorities for managing invasive species. Four categories are identified as program elements, prevention, early detection and rapid response, control and management, and rehabilitation and restoration. Long-term and short-term actions are discussed.

91. **U.S. General Accounting Office. 1997.** Agricultural inspection: improvements needed to minimize threat of foreign pests and diseases. Rep. GAO/RCED-97-102. Washington, DC: U.S. General Accounting Office: 1-29.

This report emphasizes the inadequate funding Animal and Plant Health Inspection Service (APHIS) has for its inspection services. Recommendations for improvement are given.

92. **van Manen, F.T.; Clark, J.D.; Schlarbaum, S.E.; *et al*. 2002.** A model to predict the occurrence of surviving butternut trees in the Southern Blue Ridge Mountains. In: Scott, J.M.; *et al*., eds. Predicting species occurrences—issues of accuracy and scale. Washington, DC: Island Press: 491-497.

This GIS-based model was designed to locate areas where butternut could survive. These locations could then be surveyed for resistant butternut trees to be used in restoration. The database was built using information collected from existing butternut populations in the Great Smoky Mountains National Park.

93. **Vettraino, A.M.; Barzanti, G.P.; Bianco, M.C.; *et al*. 2002.** Occurrence of *Phytophthora* species in oak stands in Italy and their association with declining oak trees. Forest Pathology. 32: 19-28.

This survey of oaks in Italy isolated *Phytophthora* at 19 of 30 sites. Most frequently isolated was *P. citricola* followed by *P. quercina*. *P. quercina* was found to cause fine root damage but not mortality in oak trees. *P. quercina's* presence weakens trees, making them more susceptible to crown damage. There was no significant correlation between any other isolated *Phytophthora* and crown damage.

94. **Wallner, W.E. 1996.** Invasive pests ('biological pollutants') and US forests: whose problem, who pays? EPPO Bulletin. 26: 167-180.

This article discusses the economical and ecological impacts of invasive pests. Included is a review of the impacts of previously introduced invasives and some suggestions for ways to prevent future introductions at both the domestic and international level.

95. **Webber, J.; Gibbs, J.; Hendry, S. 2004.** *Phytophthora* disease of alder. 3d ed. Rep. Inf. Note 006. Edinburgh: Forestry Commission. 6 p.

This article discusses the impact of *Phytophthora alni* on alders in Britain. Results of a 10-year survey are presented. Some discussion on controlling the spread of the disease is included.

Subject Index Citation Number

Prevention

Early Detection and Rapid Response

Control and Management

Rehabilitation and Restoration

Organisms

Seeland, T.M.; Ostry, M.E.; Venette, R.; Juzwik, J.
2006. **An annotated bibliography of invasive tree pathogens *Sirococcus clavigignenti-juglandacearum, Phytophthora alni,* and *Phytophthora quercina* and of regulatory policy and management practices for invasive species.** Gen. Tech. Rep. NC-270. St. Paul, MN: U.S. Department of Agriculture, Forest Service, North Central Research Station. 17 p.

Provides a database of selected literature pertaining to the prevention, early detection and rapid response, control and management, and rehabilitation and restoration related to three invasive fungal pathogens of forest trees. Literature addressing regulatory policy and management practices for invasive species is also included.

KEY WORDS: butternut canker, oak decline, alder mortality, exotic pathogens, risk assessment, forest management.

MISSION STATEMENT

We believe the good life has its roots in clean air, sparkling water, rich soil, healthy economies and a diverse living landscape. Maintaining the good life for generations to come begins with everyday choices about natural resources. The North Central Research Station provides the knowledge and the tools to help people make informed choices. That's how the science we do enhances the quality of people's lives.

For further information contact:

North Central
Research Station
USDA Forest Service
1992 Folwell Ave., St. Paul, MN 55108