

## *Neonectria faginata*

**System:** Terrestrial

Kingdom	Phylum	Class	Order	Family
Fungi	Ascomycota	Sordariomycetes	Hypocreales	Nectriaceae

<b>Common name</b>	beech bark canker (English), beech bark disease (English), BBD (English)
<b>Synonym</b>	<i>Nectria coccinea</i> , var. <i>faginata</i> M.L. Lohman, A.M.J. Watson & Ayers 1943
<b>Similar species</b>	<i>Neonectria coccinea</i> , <i>Neonectria ditissima</i>
<b>Summary</b>	Ascomycete <i>Neonectria</i> fungi along with beech scale ( <a href="#">Cryptococcus fagisuga</a> ) form the disease-complex responsible for beech bark disease (BBD) of American and European beech. In North America <i>N. faginata</i> and <i>N. ditissima</i> are responsible for the disease on American beech, whereas in Europe <i>N. ditissima</i> and <i>N. coccinea</i> affect European beech. <i>N. faginata</i> has only been recorded to infect American beech and has not been recorded outside North America, although genetic analysis suggests <i>N. faginata</i> is native to Europe. Beech scale infests mainly larger sized beech trees, feeding on host tissues and causing small fissures on the bark. This initial damage to the tree allows <i>Neonectria</i> to enter the tree, which kills host tissue and eventually girdles the tree causing it to die. BBD can dramatically alter forest stand composition and structure, through loss of large trees and proliferation of smaller trees that originate from root sprouting. Reduction of beech nut production and loss of large trees in infected stands may affect mammals and birds that use beech nuts as important food source and old trees as habitat. Around 1% of American beech is estimated to be resistant to BBD. Research is currently focused on modes of inheritance and propagation methods.



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## Species Description

*Neonectria faginata* (= *Nectria coccinea* var. *faginata*) is an ascomycete fungi. It produces fruiting bodies (ascomata) called perithecia. Perithecia are tiny (200-300 µm diameter; 250-400µm high), lemon shaped, bright red and occur in clusters of 7-15 on reddish-orange stroma in cracks of living or dead bark. Each perithecium contains sacs (asci) that are filled with sexual ascospores. Asci are narrowly clavate with ascospores arranged uniseriately within. Ascospores are ellipsoid to broadly ellipsoid, measuring 10.5-12.5 x 5-6 µm and are ornamented with regularly scattered warts. On some trees perithecia are abundant, causing large areas of the bark to appear red.

The imperfect (anamorphic) asexual state of *N. faginata* is *Cylindrocarpon faginum*. *C. faginum* produces both micro- and macroconidia. Microconidiophores form as simple lateral branches 11-15 x 3 µm. Microconidia are transparent, cylindrical, usually non-septate, 11-14 x 3 µm. Microconidia are produced during saprophytic growth on infested bark and are spread by water films. Macroconidiophores initially formed sparsely from simple conidiophores, but later become restricted to sporodochia developing as stromatic cushions, 15-20 x 3-4 µm. Macroconidia are very long, up to 120 µm, strongly curved and cylindrical, and are produced on dead bark (Lonsdale & Sherriff, 1983 in Houston, 1994a; McCullough *et al.*, 2003; Castlebury *et al.*, 2006; MycoBank, 2007).

A full, detailed description and images of *N. faginata* are available in Castlebury *et al.* (2006).

## Lifecycle Stages

The imperfect (anamorphic) state of *Neonectria faginata* is *Cylindrocarpon faginum* C. Booth 1966 (Mycobank, 2007). *C. faginum* produces both micro- and macroconidia. Microconidia which can spread in water films are produced during saprophytic growth on infested bark. Macroconidia are produced on dead bark in sporodochial pustules which erupt through the thin outer bark. *Neonectria faginata* produces ascospores within perithecia that usually occur in clusters, often where sporodochia had occurred. Both macroconidia and ascospores are dispersed by wind and water, and are the agents responsible for infecting new trees (Houston, 1994a).

## Habitat Description

American beech (*Fagus sylvatica*) appears to be the sole host of *Neonectria faginata* (Plante et al. 2002). While its native range is thought to be Europe, it has not actually been recorded outside North America (Mahoney et al., 1999; Castlebury et al., 2006).

The fungus requires prior infestation of American beech by the scale insect *Cryptococcus fagisuga*. The scale insect causes damage to host cells and results in small fissures on the bark that allows *N. faginata* to enter the tree. Indeed the most important factor determining the course of infection by *N. faginata* and other *Neonectria* species is the level of scale infestation. Heavy infestations allow *Neonectria* to spread rapidly within the bark (Houston, 1994a). High rainfall is thought to be detrimental to beech scale and *N. faginata*, as it may wash crawlers from trees and affect *Neonectria* spore production and dissemination; particularly the wind dispersed *Cylindrocarpon faginum* stage (Houston, 1988). Cold temperatures also reduce the overwintering second-instar beech scale populations in the winter (Houston, 1988). There appears to be a direct connection between climate and beech scale insect populations. In northern latitudes beech scale is limited by low winter temperature; minimum daily temperatures of -34 °C or below correlate with scale population dieback (Houston & Valentine, 1988 in Dukes et al., 2009).

*Neonectria* appear to only be limited geographically by the current distribution of beech scale, suggesting that they are not constrained by climate. In fact, perithecium production may be highest in winter as host dormancy reduces the capacity of trees to resist infection (Gove & Houston, 1996 in Dukes et al., 2009). The effect of future climate change scenarios of disease dynamics is unknown, but increased CO<sub>2</sub> may enhance tree growth and thus increase susceptibility. Alternatively, increases in CO<sub>2</sub> tend to decrease tissue nitrogen concentration, possibly decreasing bark nitrogen and thus susceptibility to scale attack. Increases in the frequency and severity of storms may influence the longevity of infected trees which are highly vulnerable to windthrow (Dukes et al., 2009).

## General Impacts

Beech bark disease (BBD) is caused by the combined impacts of beech scale insect (*Cryptococcus fagisuga*) and several species of ascomycete fungi in the genus *Neonectria*. BBD affects American (*Fagus grandifolia*) and European beech (*F. sylvatica*). Two principal species of *Neonectria fungi* are associated with BBD in North America. The probably introduced *Neonectria faginata* only infects *F. grandifolia* and is the main species involved with the disease. Native *N. ditissima* (*N. galligena*) affects a range of tree species, including beech (Houston, 1994a). In many cases *N. faginata* spreads to stands infected with *N. ditissima* and replaces this species as the dominant pathogen (Houston, 1994b; Kasson *et al.*, 2009). A third species *N. ochroleuca* (now named *Bionectria ochroleuca*) has been found in association with BBD in some regions of the United States (Houston, 2005). In Europe the fungi associated with BBD are *N. ditissima* and *N. coccinea* (Twery & Patterson, 1984; Castlebury *et al.*, 2006).

The beech scale insect feeds on host parenchyma cells which collapse and die, resulting in small fissures on the bark that allow *Neonectria* to enter the tree. Heavy infestations of scale allow *Neonectria* to spread rapidly within the bark (Houston, 1994a). As the fungal mycelia grow, large areas of tissues become weakened and die, sometimes causing cankers on the trunk and branches. Sometimes red-brown liquid oozes from the bark tissues killed by the fungi, and the foliage of severely affected trees may become sparse and turn yellow (LeGuerrier *et al.*, 2003). If enough tissue is killed the tree will be girdled and die (Koch *et al.*, 2010). The course of the disease may take as little as two years, but other trees may linger for several years.

Much research has suggested that BBD mainly affects large, older trees, and may cause up to 80% mortality of beech within a stand (Houston, 1994a). Death of older trees leads to gradual gaps in the canopy. This gives the opportunity for other tree species to take over, sometimes leading to drastic changes in the composition and structure of stands (Twery & Patterson, 1984; Runkle, 1990; Wiggins *et al.*, 2004). Particularly in stands dominated by BBD-tolerant species such as eastern hemlock (*Tsuga canadensis*) and sugar maple (*Acer saccharum*); these species dominate and American beech may become a minor component of the stand (Twery & Patterson, 1984).

However in most forest stands BBD favours the development of dense beech thickets that interfere with the regeneration of other trees (Houston, 1994a; Garnas *et al.*, 2011), due to beech's propensity to reproduce vegetatively via adventitious root sprouts, especially from damaged root sprouts (Garnas *et al.*, 2011). Thus in many forests there is actually an increase in beech volume accumulation, particularly 10-20 years after BBD invasion (Morin *et al.*, 2007).

Beech is a highly important tree for many birds and mammals due to the habitat large old trees provide and for the beechnuts produced during mast years. Loss of larger trees may reduce food and habitat and have negative impacts for animals, which may ramify through the ecosystem (Lovett *et al.*, 2006; Wiggins *et al.*, 2004).

Diseased trees are more prone to "beech snap" during high wind events. This poses a threat to people and personal property where trees occur in campgrounds, recreation areas or near homes (McCullough *et al.*, 2003; Heyd, 2005). Alteration to beech composition may also have economic impacts, both negative and positive (Garnas *et al.*, 2011).

For a detailed account of the impacts of beech bark disease please read Impacts of Beech Bark Disease

## Management Info

Most control methods focus on reducing populations of the beech scale, as *Neonectria* are unable to colonise trees that have not been previously infested with the scale. Thus control of *Cryptococcus fagisuga* is likely to slow the spread of BBD (Wiggins *et al.*, 2004).

**Cultural:** Thinning and removal of infected or susceptible trees, while retaining resistant trees is a commonly used management strategy. This is important for decreasing long-term susceptibility and vulnerability of forests to beech bark disease. Potentially resistant trees can be identified by smooth bark and vigour. In contrast, large overmature trees, trees with rough bark, and trees with wounds, broken tops or other obvious problems are most likely to be infested by beech scale and most vulnerable to *Neonectria* infection (McCullough *et al.*, 2003). However such practices not feasible in large areas of natural forest due to labour, financial and practical constraints (Wiggins *et al.*, 2004).

**Physical:** Physical removal of scale insects by scrubbing trees, high pressure water, or use of petroleum-based oils, which cover and suffocate scale insects may be used on individual high-value ornamental or yard trees (McCullough *et al.*, 2003).

**Chemical:** There is no practical chemical control for beech scale (Pond, 2008), although insecticides may be used for individual high-value ornamental or yard trees (McCullough *et al.*, 2003). Herbicides may be used in some cases to control beech regeneration, in order to minimise root sprouting and the creation of dense beech thickets (McCullough *et al.*, 2003). Pesticides are not acceptable control options in large natural areas because of labour, financial, environmental and practical constraints (Wiggins *et al.*, 2004).

**Biological:** The most desirable option for control of BBD is a biological control agent of *C. fagisuga* (Wiggins *et al.*, 2004). A number of natural predators and pathogens of *C. fagisuga* have been identified including coccinellids, mites, gall gnats and a fungus (Shingo, 1964 in Houston, 1994a; Wiggins *et al.*, 2004; Dukes *et al.*, 2009). However none are effective in stopping its spread to date (Pond, 2008), and much further research is required (Wiggins *et al.*, 2004).

**Genetic:** An estimated 1% of American beech trees are resistant to scale insect infestation, and thus BBD. The cause of resistance to BBD remains unidentified (Koch *et al.*, 2007), although in European beech resistance appears to be due to anatomical features that act as barriers to infestation (Lonsdale, 1983a in Houston, 2005), whereas in American beech resistance may be associated with less total and amino nitrogen concentration (Wargo, 1988 in Houston, 2005). Recent findings suggest that resistance to BBD ranges from partial to total resistance (Ramirez *et al.*, 2007).

Currently the only known method to identify resistant trees is the artificial infestation method developed by Houston (1982). Drawbacks to this method include the minimum 1-year wait for results and the reliance on live scale eggs which could result in spread of the insect. Thus much research is focused on identification of genetic markers for resistance, trials to clarify modes of inheritance via cross-breeding resistant and susceptible individuals, and methods of propagation via somatic embryogenesis (Koch & Carey, 2005; Loo *et al.* 2005; Pond, 2008).

For a detailed account of management options for beech bark disease please read Management of Beech Bark Disease

**Principal source:** Castlebury, Lisa A.; Rossman, Amy Y.; Hyten, Aimee S., 2006. Phylogenetic relationships of *Neonectria/Cylindrocarpon* on *Fagus* in North America. Canadian Journal of Botany. 84(9):1417-1433.

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## ALIEN RANGE

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## BIBLIOGRAPHY

### 57 references found for *Neonectria faginata*

#### Management information

Evans, Celia A.; Lucas, Jennifer A.; Twery, Mark J. 2005. Beech Bark Disease: Proceedings of the Beech Bark Disease Symposium. Gen. Tech. Rep. NE-331. Newtown Square PA, US. Department of Agriculture Forest Service, Northern Research Station. 149 p.

**Summary:** Available from: [http://www.fs.fed.us/ne/newtown\\_square/publications/technical\\_reports/pdfs/2005/ne\\_gtr331.pdf](http://www.fs.fed.us/ne/newtown_square/publications/technical_reports/pdfs/2005/ne_gtr331.pdf) [Accessed 10 January 2011]

Garnas R. Jeffrey, Matthew P. Ayres, Andrew M. Liebhold and Celia Evan, 2011. Subcontinental impacts of an invasive tree disease on forest structure and dynamics. *Journal of Ecology* 2011, 99, 532-541

Heyd, Robert L. 2005. Managing beech bark disease in Michigan. In: C.A. Evans, J.A. Lucas & Twery, M.J. (Eds) Beech bark disease. Proceedings of the beech bark disease symposium. Saranac Lake, NY, 16-18 June 2004. USDA Forest Service, NE Res Station, Gen Tech Rep NE-331. pp. 128-132.

Koch, Jennifer L. & Carey, David W. 2005. The genetics of resistance of American beech to beech bark disease: knowledge through 2004. In: C.A. Evans, J.A. Lucas & Twery, M.J. (Eds) Beech bark disease. Proceedings of the beech bark disease symposium. Saranac Lake, NY, 16-18 June 2004. USDA Forest Service, NE Res Station, Gen Tech Rep NE-331. pp. 98-105.

Koch, Jennifer L.; Carey, David W.; Mason, Mary E.; Nelson, C. Dana, 2010. Assessment of beech scale resistance in full- and half-sibling American beech families. *Canadian Journal of Forest Research*. 40(2). FEB 2010. 265-272.

Loo, Judy; Ramirez, M. & Krasowski, M. 2005. American beech vegetative propagation and genetic diversity. In: C.A. Evans, J.A. Lucas & Twery, M.J. (Eds) Beech bark disease. Proceedings of the beech bark disease symposium. Saranac Lake, NY, 16-18 June 2004. USDA Forest Service, NE Res Station, Gen Tech Rep NE-331. pp. 106-112.

McCullough G. Deborah, Robert Heyd, and Joseph G. O'Brien, 2003. *Biology and Management of Beech Bark Disease Michigan's Newest Exotic Forest Pest*. Michigan Society of American Foresters

**Summary:** Available from: <http://michigansaf.org/ForestInfo/Health/BBdisease.htm> [Accessed 10 January 2011]

Morris, Ashley B.; Small, Randall L.; Cruzan, Mitchell B., 2002. Investigating the relationship between *Cryptococcus fagisuga* and *Fagus grandifolia* in Great Smoky Mountains National Park. *Southeastern Naturalist*. 1(4). 2002. 415-424.

Pond, Sharon E. 2008. Conservation and propagation of American beech (*Fagus grandifolia* Ehrh.) through somatic embryogenesis. *Propagation of Ornamental Plants*. 8(2). 2008. 81-86.

Wainhouse D. 1980. Dispersal of First Instar Larvae of the Felted Beech Scale, *Cryptococcus fagisuga*. *Journal of Applied Ecology*, Vol. 17, No. 3 (Dec., 1980), pp. 523-532

Wiggins, Gregory J.; Grant, Jerome F.; Welbourn, W. Cal, 2001. *Allothrombium mitchelli* (Acari: Trombididae) in the Great Smoky Mountains National Park: Incidence, seasonality, and predation on beech scale (Homoptera: Eriococcidae). *Annals of the Entomological Society of America*. 94(6). November, 2001. 896-901.

#### General information

Beachy, Brian L. & Storer, Andrew J. Wood-infesting insect abundance and community structure in relation to beech bark disease. 2005. In: C.A. Evans, J.A. Lucas & Twery, M.J. (Eds) Beech bark disease. Proceedings of the beech bark disease symposium. Saranac Lake, NY, 16-18 June 2004. USDA Forest Service, NE Res Station, Gen Tech Rep NE-331. pp. 94.

Bissessar S.; McLaughlin D. L.; Linzon, 1985. The 1st occurrence of the beech scale insect *Cryptococcus fagisuga* on American beech *Fagus grandifolia* trees in Ontario, Canada. *Journal of Arboriculture*. 11(1). 1985. 13-14.

Castlebury, Lisa A.; Rossman, Amy Y.; Hyten, Aimee S., 2006. Phylogenetic relationships of *Neonectria/Cylindrocarpus* on *Fagus* in North America. *Canadian Journal of Botany*. 84(9). SEP 2006. 1417-1433.

Covassi M., 1975. New records on the chorology of *Cryptococcus fagisuga*, new record in Italy and Corsica, France [Homoptera Cryptococcidae] *Redia*. 56 1975. 555-564.

**Summary:** Several localities of the Italian Alps and the Apennines where the woolly beech scale *C. fagisuga* was found are listed. The discovery of this scale in Corsica [France] and also in Sicily is reported for the first time on M. Etna *C. fagisuga* reaches its European southern limit together with its host plants.

Dukes, Jeffrey S.; Pontius, Jennifer; Orwig, David; Garnas, Jeffrey R.; Rodgers, Vikki L.; Brazee, Nicholas; Cooke, Barry; Theoharides, Kathleen A.; Stange, Erik E.; Harrington, Robin; Ehrenfeld, Joan; Gurevitch, Jessica; Lerdau, Manuel; Stinson, Kristina; Wick, Robert; Ayres, Matthew, 2009. Responses of insect pests, pathogens, and invasive plant species to climate change in the forests of northeastern North America: What can we predict? *Canadian Journal of Forest Research*. 39(2). FEB 2009. 231-248.

Faison, Edward K.; Houston, David R., 2004. Black bear foraging in response to beech bark disease in northern Vermont. *Northeastern Naturalist*. 11(4). 2004. 387-394.

Fernandez M. R.; Boyer M. G., 1988. Beech bark disease: A survey of the Toronto area Canada. *Canadian Plant Disease Survey*. 68(2). 1988. 157-160.

Fernandez M. R.; Boyer M. G., 1989. Beech bark mycoflora and its distribution in relation to the presence of the scale insect *Cryptococcus fagisuga* Lind. *Canadian Plant Disease Survey*. 69(2). 1989. 101-104.

Forrester, Jodi A.; McGee, Gregory G.; Mitchell, Myron J., 2003. Effects of beech bark disease on aboveground biomass and species composition in a mature northern hardwood forest, 1985 to 2000. *Journal of the Torrey Botanical Society*. 130(2). April-June 2003. 70-78.

Gavin, David G.; Peart, David R., 1993. Effects of beech bark disease on the growth of American beech (*Fagus grandifolia*). *Canadian Journal of Forest Research*. 23(8). 1993. 1566-1575.

Griffin, Jacob M.; Lovett, Gary M.; Arthur, Mary A.; Weathers, Kathleen C., 2003. The distribution and severity of beech bark disease in the Catskill Mountains, N.Y. *Canadian Journal of Forest Research*. 33(9). September 2003. 1754-1760.

Gwiazdowski, Rodger A.; Van Driesche, Roy G.; Desnoyers, Adrienne; Lyon, Suzanne; Wu, San-An; Kamata, Naoto; Normark, Benjamin B., 2006. Possible geographic origin of beech scale, *Cryptococcus fagisuga* (Hemiptera : Eriococcidae), an invasive pest in North America. *Biological Control*. 39(1). OCT 2006. 9-18.



- Hane, Elizabeth N., 2003. Indirect effects of beech bark disease on sugar maple seedling survival. *Canadian Journal of Forest Research*. 33(5). May 2003. 807-813.
- Houston, David R., 1994b. Temporal and spatial shift within the Nectria pathogen complex associated with beech bark disease of *Fagus grandifolia*. *Canadian Journal of Forest Research*. 24(5). 1994. 960-968.
- Houston, David R. 2005. Beech bark disease: 1934 to 204: what's new since Ehrlich? In: C.A. Evans, J.A. Lucas & Twery, M.J. (Eds) *Beech bark disease. Proceedings of the beech bark disease symposium*. Saranac Lake, NY, 16-18 June 2004. USDA Forest Service, NE Res Station, Gen Tech Rep NE-331. pp 2-13.
- Houston D. R. 1994a. Major New Tree Disease Epidemics: Beech Bark Disease! *Annu. Rev. Phytopathol.* 1994. 32:75-87
- Houston D. R.; Parker E. J.; Lonsdale, 1979. Beech bark disease patterns of spread and development of the initiating agent *Cryptococcus fagisuga*. *Canadian Journal of Forest Research*. 9(3). 1979. 336-344.
- Houston D. R.; Valentine H. T., 1988. Beech bark disease the temporal pattern of cankering in aftermath forests of Maine USA. *Canadian Journal of Forest Research*. 18(1). 1988. 38-42.
- Jakubas, Walter J.; McLaughlin, Craig R.; Jensen, Paul G. & McNulty, Stacy A. 2005. Alternate year beechnut production and its influence on bear and marten populations. In: C.A. Evans, J.A. Lucas & Twery, M.J. (Eds) *Beech bark disease. Proceedings of the beech bark disease symposium*. Saranac Lake, NY, 16-18 June 2004. USDA Forest Service, NE Res Station, Gen Tech Rep NE-331. pp. 79-87.
- Kasson, Matthew T.; Livingston, William H., 2009. Spatial distribution of *Neonectria* species associated with beech bark disease in northern Maine. *Mycologia*. 101(2). MAR-APR 2009. 190-195
- Latty, Erika F.; Canham, Charles D.; Marks, Peter L., 2003. Beech bark disease in northern hardwood forests: The importance of nitrogen dynamics and forest history for disease severity. *Canadian Journal of Forest Research*. 33(2). February 2003. 257-268.
- Leak, William B., 2006. Fifty-year impacts of the beech bark disease in the Bartlett Experimental Forest, New Hampshire. *Northern Journal of Applied Forestry*. 23(2). JUN 2006. 141-143.
- Le Guerrier, Catherine; Marceau, Danielle J.; Bouchard, Andre; Brisson, Jacques, 2003. A modelling approach to assess the long-term impact of beech bark disease in northern hardwood forest. *Canadian Journal of Forest Research*. 33(12). December 2003. 2416-2425.
- Loo, Judy A., 2009. Ecological impacts of non-indigenous invasive fungi as forest pathogens. *Biological Invasions*. 11(1). JAN 2009. 81-96.
- Lovett, Gary M.; Canham, Charles D.; Arthur, Mary A.; Weathers, Kathleen C. & Fitzhugh, Ross D. 2006. Forest ecosystem responses to exotic pests and pathogens in Eastern North America. *Bioscience* 56. MAY 2005. 395-405.
- Mackenzie, M.; Iskra, A. J., 2005. The first report of beech bark disease in Ohio comes nineteen years after the first report of the initiating scale. *Plant Disease*. 89(2). February 2005. 203.
- Mahoney, Eileen M.; Milgroom, Michael G.; Sinclair, Wayne A. 1999. Origin, genetic diversity, and population structure of *Nectria coccinea* var. *faginata* in North America. *Mycologia*. 91(4). FEB 1999. 583-592.
- McGee, Gregory G., 2000. The contribution of beech bark disease-induced mortality to coarse woody debris loads in northern hardwood stands of Adirondack Park, New York, U.S.A. *Canadian Journal of Forest Research*. 30(9). September, 2000. 1453-1462.
- McLaughlin, C.R.; Matula, G.J.; O'Connor, R.J. 1993. Synchronous reproduction by Maine black bears. *International Conference of Bear Research and Management*
- Mielke M. E.; Haynes C.; Macdonald W. L., 1982. Beech scale and *Nectria galligena* on beech in the Monongahela Forest West Virginia USA. *Plant Disease*. 66(9). 1982. 851-852.
- Morin, Randall S.; Liebhold, Andrew M.; Tobin, Patrick C.; Gottschalk, Kurt W.; Luzader, Eugene, 2007. Spread of beech bark disease in the eastern United States and its relationship to regional forest composition. *Canadian Journal of Forest Research*. 37(4). APR 2007. 726-736.
- Munck, I. A.; Manion, P. D., 2006. Landscape-level impact of beech bark disease in relation to slope and aspect in New York State. *Forest Science*. 52(5). OCT 2006. 503-510.
- [Mycobank. 2007. \*Neonectria faginata\* \(M.L. Lohman, A.M.J. Watson & Ayers\) Castl. & Rossman 2006.](#)
- Summary:** Available from: <http://www.mycobank.org/Mycotaxo.aspx?Link=T&Rec=504379> [Accessed 9 March 2011]
- O'Brien, J. G.; Ostry, M. E.; Mielke, M. E.; Mech, R.; Heyd, R. L.; McCullough, D. G., 2001. First report of beech bark disease in Michigan. *Plant Disease*. 85(8). August, 2001. 921.
- Papaik, Michael J.; Canham, Charles D.; Latty, Erika F.; Woods, Kerry D., 2005. Effects of an introduced pathogen on resistance to natural disturbance: beech bark disease and windthrow. *Canadian Journal of Forest Research*. 35(8). AUG 2005. 1832-1843.
- Petrillo, Holly A. & Witter, John. A. 2005. Michigan beech bark disease monitoring and impact analysis. In: C.A. Evans, J.A. Lucas & Twery, M.J. (Eds) *Beech bark disease. Proceedings of the beech bark disease symposium*. Saranac Lake, NY, 16-18 June 2004. USDA Forest Service, NE Res Station, Gen Tech Rep NE-331. pp. 48-51.
- Plante, Françoise; Hamelin, Richard C.; Bernier, Louis. 2002. A comparative study of genetic diversity of populations of *Nectria galligena* and *N. coccinea* var. *faginata* in North America. *Mycology Research*. 106(2). FEB 2002. 183-193.
- Ramirez, M.; Loo, J.; Krasowski, M. J., 2007. Evaluation of resistance to the beech scale insect (*Cryptococcus fagisuga*) and propagation of American beech (*Fagus grandifolia*) by grafting. *Silvae Genetica*. 56(3-4). 2007. 163-169
- Runkle J. R., 1990. Eight years change in an old *Tsuga canadensis* woods affected by beech bark disease. *Bulletin of the Torrey Botanical Club*. 117(4). 1990. 409-419.
- [Storer, Andrew J.; Rosemier, Justin N.; Beachy, Brian L. & Flaspohler, David J. 2005. Potential effects of beech bark disease and decline in beech abundance on birds and small mammals. In: C.A. Evans, J.A. Lucas & Twery, M.J. \(Eds\) \*Beech bark disease. Proceedings of the beech bark disease symposium\*. Saranac Lake, NY, 16-18 June 2004. USDA Forest Service, NE Res Station, Gen Tech Rep NE-331. pp 72-78.](#)
- Summary:** Available from: [http://www.fs.fed.us/ne/newtown\\_square/publications/technical\\_reports/pdfs/2005/331papers/storer331.pdf](http://www.fs.fed.us/ne/newtown_square/publications/technical_reports/pdfs/2005/331papers/storer331.pdf) [Accessed March 11 2011]
- Teale, Stephen A.; Letkowski, Steven; Matusick, George; Stehman, Stephen V.; Castello, John D., 2009. Quantitative, Nondestructive Assessment of Beech Scale (Hemiptera: Cryptococcidae) Density Using Digital Image Analysis of Wax Masses. *Environmental Entomology*. 38(4). AUG 2009. 1235-1240.
- Twery M. J.; Patterson W. A. III., Variations in beech bark disease and its effects on species composition and structure of Northern hardwood stands in Central New England USA. *Canadian Journal of Forest Research*. 14(4). 1984. 565-574.
- [UniProt Taxonomy, 2011. \*Varietas Neonectria coccinea\* var. \*faginata\*](#)
- Summary:** Available from: <http://pir.uniprot.org/taxonomy/397354> [Accessed 10 January 2011]

Weeks, Brian C.; Hamburg, Steven P.; Vadeboncoeur, Matthew A., 2009. Ice storm effects on the canopy structure of a northern hardwood forest after 8 years. *Canadian Journal of Forest Research*. 39(8). AUG 2009. 1475-1483.

Wiggins, Gregory J.; Grant, Jerome F.; Windham, Mark T.; Vance, Robert A.; Rutherford, Brenda; Klein, Robert; Johnson, Kristine; Taylor, Glenn, 2004. Associations between causal agents of the beech bark disease complex (*Cryptococcus fagisuga* (Homoptera: Cryptococcidae) and *Nectria* spp.) in the Great Smoky Mountains National Park. *Environmental Entomology*. 33(5). October 2004. 1274-1281.

Witter, John A.; Stoyenoff, Jennifer L.; Petrillo, Holly A.; Yocum, Julie L.; Cohen, James. I. 2005. Effects of beech bark disease on trees and ecosystems. In: C.A. Evans, J.A. Lucas & Twery, M.J. (Eds) *Beech bark disease. Proceedings of the beech bark disease symposium*. Saranac Lake, NY, 16-18 June 2004. USDA Forest Service, NE Res Station, Gen Tech Rep NE-331. pp. 28-35.