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Phytophthora on *Abies* spp. (true firs)

Julius Kühn-Institut, Federal Research Centre for Cultivated Plants

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Importance of *Abies* spp.

Approximately 50 species belong to the genus *Abies* and they are mainly native to the temperate regions of the northern hemisphere (http://www.discoverlife.org). They play a very important environmental role in their regions of origin. Several species are also important for timber production outside their native range.

Others are highly appreciated as ornamentals in landscape plantings. Because of their natural conical shape, color and strong branches for holding ornaments, true firs, especially species with excellent postharvest needle retention, are also ideally suited for use as Christmas trees and bough production. In Europe, the most common species grown as Christmas trees is Nordmann fir, while in the USA, Fraser (*Abies fraseri*) and noble fir (*Abies procera*) predominate.

Other *Abies*-species marketed as Christmas trees include balsam fir (*A. balsamea*) grand fir (*A. grandis*), Korean fir (*Abies koreana*), Siberian fir (*A. sibirica*), subalpine fir (*A. lasiocarpa*), Turkish fir (*A. bornmuelleriana*), and white fir (*A. concolor*). Noble fir is the main species for bough production both in Europe and USA.

Phytophthora species

A number of *Phytophthora* spp. has been isolated from true firs worldwide. The following is a partial list of species that have been reported on specific hosts:

***Phytophthora* species**	**Disease symptoms**	***Abies* species**	**Reference**
cactorum	root rot stem canker branch flagging	*amabilis* *balsamea* *balsamea* var. *phanerolepis* *concolor* *fraseri* *magnifica* var. *shastensis* *procera*	Adams & Bielenin, 1988 Chastagner *et al.*, 1995 Hamm & Hansen, 1982 Hong & Marston, 2005
cambivora	root rot stem canker branch flagging	*procera*	Chastagner *et al.*, 1995 Talgø et al., 2006
capsici		*fraseri*	Quesada-Ocampo *et al.*, 2009
cinnamomi	root rot stem canker branch flagging	*fraseri* *procera*	Chastagner *et al.*, 1995 Grand & Lapp, 1974
citricola	root rot shoot blight	*balsamea* *concolor* *fraseri* *magnifica* *procera*	Adams & Bielenin, 1988 McCain & Scharpf, 1986 Shew & Benson, 1981
citrophthora	root rot collar rot	*lasiocarpa* var. *arizonica*	Józsa *et al.*, 2011
cryptogea	root rot stem canker branch flagging	*procera*	Chastagner *et al.*, 1995
drechsleri	root rot stem canker branch flagging	*fraseri* *procera*	Benson *et al.*, 1976 Chastagner *et al.*, 1995
gonapodyides	root rot stem canker branch flagging	*procera*	Chastagner *et al.*, 1995
inundata-like		*nordmanniana*	Talgø *et al.*, 2007
megasperma	root rot stem canker	*lasiocarpa* *procera*	Chastagner *et al.*, 1995 Talgø *et al.*, 2007
pseudotsugae	root rot stem canker branch flagging	*procera*	Chastagner *et al.*, 1995
ramorum[1]	root rot stem canker	*concolor* *magnifica* *grandis*	Chastagner & Riley, 2010 Riley *et al.*, 2011

1 - in the European Union *P. ramorum* is a regulated organism (see chapter 'Quarantine recommendation')

Disease symptoms (see figures)

Wet conditions are necessary for the spread of *Phytophthora* spores and infection of plants. Most *Phytophthora* spp. are soil borne, which means that spores are spread in water films in infested soil and may cause root rot and possibly spread to stems in the form of cankers. The first visible symptoms caused by soil borne *Phytophthora* spp. can include a general discoloration of foliage (chlorotic, greyish, and finally necrotic) or one or more dying basal branches (flagging). The foliage discoloration is due to lack of water and nutrients as the pathogen destroys the vascular system.

Flagging indicates that an aboveground canker has developed, commonly extending upwards on one side of the tree and killing the branches in its path. Multiple cankers and/or spiral development of a single canker may girdle the tree. The cankers appear slightly sunken, sometimes cracked along the margins, and darker than the healthy bark. Heavy resin flow may occur. Beneath the bark of the cankered areas, the tissue appears brick red with a sharp border at the healthy, green tissue along the leading edges. Symptoms caused by *P. cambivora* on noble fir in Norway are presented in Figure 1.

In some cases, especially in nurseries, lower foliage may be infected when water splashes contaminated soil onto the foliage. The use of contaminated irrigation water may cause shoot blight, which is also a common symptom caused by airborne *Phytophthora* spp. like *P. ramorum*. The presence of *P. ramorum* spores during bud break and shoot elongation may also cause infection and subsequent canker development on branches of susceptible fir species.

Possibility of symptom confusion

Both Armillaria root rot (*Armillaria* spp.) and Annosus root rot (*Heterobasidion annosum*) may kill the roots of true firs, resulting in discolored foliage similar to the symptoms caused by *Phytophthora* spp., but the two pathogens produce clear signs that distinguish the diseases they cause from Phytophthora root rot. *Armillaria* spp. produce root-like rhizomorphs that are visible on the roots and root collar, white mycelial fans beneath the bark near the root collar, and fruiting bodies at stem bases.

H. annosum produces a thin, colorful (pink, purple, red, brown) mycelial layer between the bark and the wood as well as conks on root collars. The conks are often hidden by litter, but a typical, irregularly-shaped dark stain in the older wood of the trunk is normally a reliable symptom and sufficient for diagnosing the pathogen.

Disease development

Damage potential by *Phytophthora* spp. on Christmas trees is considered moderate to high (Chastagner & Byther, 1997). *Phytophthora* spp. produce motile spores under wet conditions. They can actively swim for a few millimeters in water, enough to reach and infect nearby roots, or be transported over longer distances in windborne droplets or by water movement in soil or along waterways.

Soil borne *Phytophthora* spp. can spread up the roots and kill the cambium and inner bark. Disease development depends on several factors; health of the seedling transplants, soil type, weather conditions, and the *Phytophthora* and *Abies* species in question. Disease-free nursery stock is essential for a good outcome. Plants grown in well-drained soils, as opposed to poorly-drained hea-

vy soils, are less prone to *Phytophthora* problems. In cases where transplants are latently infected (e.g. where the pathogen is present, but symptoms are suppressed by fungicides), and then are planted in saturated soil, mortality can be very high in a short period of time (Talgø et al., 2007).

Another concern is that infected transplants may introduce the pathogen into uninfested fields. The aggressiveness of different *Phytophthora* spp. varies, and some *Abies* spp. are more susceptible than others. In North Carolina (USA), *P. cinnamomi* is a well-known pathogen on native Fraser fir that is grown in Christmas tree plantations (Grand & Lapp, 1974). In the western USA, noble fir grows naturally in the mountain areas and has also become the major Christmas tree grown in plantations in the region. In Oregon and Washington State a total of eight *Phytophthora* spp. are associated with root rot development on noble fir, with *P. cactorum*, *P. cambivora*, *P. cinnamomi*, and *P. cryptogea* considered to be the most aggressive species.

Laboratory and field studies in North Carolina and in the U.S. Pacific Northwest have clearly demonstrated that there are significant differences in the susceptibility of true firs to Phytophthora root rot (Bensen *et al.*, 1997; Chastagner, 2010; Cooley *et al.*, 1988; Frampton & Benson, 2012; Hinesley *et al.*, 2000) (Fig. 2). Variation in susceptibility is dependent on the *Phytophthora* spp, host, and environmental conditions. Noble, balsam (*A. balsamea*), grand, California red (*Abies magnifica*), Fraser, and Shasta (*A. magnifica* var. *shastensis*) firs are among the more susceptible species, whereas Turkish, European silver (*A. alba*), Veitch (*A. veitchii*), Nordmann, Momi (*A. firma*), and Korean firs tend to be much less susceptible.

Diagnosis

It is not possible to identify a *Phytophthora* infection only by disease symptoms. Different diagnostic techniques like direct isolation, molecular and serological methods help to identify *Phytophthora* as the cause of the tree disease and to specify the *Phytophthora* species. Information on *Phytophthora* diagnosis on trees is given for example in http://forestphytophthoras.org/key-to-species, http://www.phytophthoradb.org, http://phytophthora-id.org and in Martin *et al.* (2012).

Please contact your national authorities (see next chapter) for help with diagnosis.

What to do in case trees are suspected to be infected?

Contact your responsible national authorities, for example:

Austria:
- Bundesforschungs- und Ausbildungszentrum für Wald, Naturgefahren und Landschaft (BWF)
  Federal Research and Training Centre for Forests, Natural Hazards and Landscape (BFW)
  Seckendorff-Gudent-Weg 8, 1131 Vienna, Austria; http://www.bfw.ac.at/
- Österreichische Agentur für Gesundheit und Ernährungssicherheit
  Austrian Agency for Health and Food Safety, Institute for Sustainable Plant Production
  Spargelfeldstraße 191, 1220 Vienna; http://www.ages.at

Belgium:
- Département Sciences du Vivant, Centre Wallon de Recherches Agronomiques
  Life Sciences Department, Walloon Agricultural Research Centre
  Rue de Liroux 4, B-5030 Gembloux;
  Anne CHANDELIER | a.chandelier@cra.wallonie.be
- Instituut voor Landbouw- en Visserijonderzoek (ILVO), Eenheid Plant -Gewasbescherming
  Institute for Agricultural and Fisheries Research, Plant Sciences Unit – Crop Protection - Gewasbescherming
  Burg. van Gansberghelaan 96 bus 2, 9820 Merelbeke
  Kurt HEUNGENS | kurt.heungens@ilvo.vlaanderen.be

Bulgaria:
- Българска Агенция по безопастност на храните: Централна лаборатория по карантина на растенията
  plant protection regional services: http://www.babh.government.bg/en/labs.html
- Агробиоинститут, Селскостопанска Академия бул 8, Драган Цанков № 8, София 1164
  Biotic Stress Group, AgroBioInstitute, Agricultural Academy
  8 Dragan Tsankov blvd., 1164 Sofia
  Славчо Славов, sbslavov@abi.bg
  Slavtcho SLAVOV | sbslavov@abi.bg

Czech Republik:
Výzkumný ústav Silva Taroucy pro krajinu a okrasné zahradnictví, v.v.i
The Silva Tarouca Research Institute for Landscape and Ornamental Gardening, Publ. Res. Institute
Květnové náměstí 391, Průhonice, 252 67, Praha západ
Matěj PANEK | panek@vukoz.cz

Denmark:
- NaturErhvervstryrelsen, Ministeriet for Fødevarer, Landbrug og Fiskeri
  The Danish AgriFish Agency, http://www.naturerhverv.fvm.dk
- Institut for Geovidenskab og Naturforvaltning, Det Natur- og Biovidenskabelige Fakultet, Københavns Universitet
  Department of Geosciences and Natural Resource Management, Faculty of Science, University of Copenhagen | www.ign.ku.dk

Finland:

- Elintarviketurvallisuusvirasto Evira, Kasvinterveysyksikkö
  Finnish Food Safety Authority Evira, Plant Health Mustialankatu 3, FI-00790 Helsinki
  http://www.evira.fi/portal/fi/kasvit/viljely_ja_tuotanto/metsanviljely/valvonta/
- Metsäntutkimuslaitos
  Finnish Forest Research Institute
  P.O. Box 18, FI-01301 Vantaa
  Anna RYTKÖNEN | anna.rytkonen@metla.fi
- Maa- ja elintarviketalouden tutkimuskeskus MTT
  Agrifood Research, MTT
  FI-31600 Jokioinen
  Päivi PARIKKA | paivi.parikka@mtt.fi.

France:

- Services Régionaux de l'Alimentation (SRAL) des Directions Régionales de l'Alimentation, de l'Agriculture et de la Forêt (DRAAF)
  Regional Plant Protection services
  http://agriculture.gouv.fr/suivi-de-la-sante-des-forets
  http://agriculture.gouv.fr/services-deconcentres
- Laboratoire de Santé végétaux, unite de Mycologie, ANSES
  French Agency for Food, Environmental and Occupational Health & Safety (ANSES)- Plant Health Laboratory, unit of mycology
  Domaine de Pixérécourt Bat E., 54220 Malzéville, France; http://www.anses.fr/PNTC01.htm;
  Nathalie SCHENCK | Nathalie.schenck@anses.fr
  Renaud IOOS | renaud.ioos@anses.fr
- Pôle interrégionaux du Département de la santé des forêts:
  Regional forest health survey organisation:
  http://agriculture.gouv.fr/departement-de-la-sante-des-forets

Germany:

- Pflanzenschutzdienstellen der Bundesländer, Adressenliste siehe:
  regional plant protection services, address list see: http://www.jki.bund.de/de/startseite/unser-service/linksammlung.html
- Julius Kühn Institut – Bundesforschungsanstalt für Kulturpflanzen (JKI), Institut für Pflanzenschutz in Gartenbau und Forst (JKI-GF)
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  Forest Research Institute, 570 06 Vassilika, Thessaloniki, Greece
  http://www.fri.gr, Στέφανος ΔΙΑΜΑΝΤΗΣ | info@fri.gr
- Ινστιτούτο Μεσογειακών Δασικών Οικοσυστημάτων & Τεχνολογίας Δασικών Προϊόντων, Τέρμα Αλκμάνος, 115 28 Ιλίσια, Αθήνα, Ελλάς
  Institute of Mediterranean Forest Ecosystems & Forest Products Technology, Terma Alkmanos, 115 28 Ilissia, Athens, Greece
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- Γεωπονικό Πανεπιστήμιο Αθηνών, Εργαστήριο Φυτοπαθολογίας, Ιερά Οδός 75, 11855 Αθήνα
  Agricultural University of Athens, Laboratory of Plant Pathology, Iera Odos 75, 11855 Athens, Greece
  http://www.aua.gr/index.php, Επαμεινώνδας ΠΑΠΛΩΜΑΤΑΣ | epaplom@aua.gr
- Μπενάκειο Φυτοπαθολογικό Ινστιτούτο, Στεφάνου Δέλτα 8, Κηφισιά, Αθήνα, 14561
  Benaki Phytopathological Institute, 8 Stefanou Delta Street, Kifissia, Athens, 14561
  http://www.bpi.gr, Ειρήνη ΒΛΟΥΤΟΓΛΟΥ | I.Vloutoglou@bpi.gr

Hungary:

- Megyei Kormányhivatalok Növény- és Talajvédelmi Igazgatóságai
  Regional offices of NFCSO, Directorate of Plant Protection and Soil Conservation
  http://www.nebih.gov.hu/elerhetosegek
- MTA ATK Növényvédelmi Intézet
  Plant Protection Institute, Centre for Agricultural Research, Hungarian Academy of Sciences
  Herman Ottó u. 15, H-1022 Budapest, Hungary;
  József BAKONYI | bakonyi.jozsef@agrar.mta.hu

Ireland:

- Department of Agriculture, Food and the Marine, Horticulture and Plant Health Division
  Backweston Agri-Campus, Celbridge, Co. Kildare, Ireland
  oliver.mcevoy@agriculture.gov.ie

Italy:

- COSVIR XI - Servizio fitosanitario centrale
  Italian Phytosanitary Service
  cosvir11@pec.politicheagricole.gov.it, http://www.politicheagricole.it/flex/cm/pages/Ser veBLOB.php/L/IT/IDPagina/2341
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Latvia:
Valsts augu aizsardzības dienests
State Plant Protection Service http://www.vaad.gov.lv/english/contacts/departments.aspx

Netherlands:
Nationaal Referentie Centrum,
Nederlandse Voedsel- en Warenautoriteit (NVWA)
National Reference Centre, NPPO
Netherlands Food and Consumer Product Safety Authority
Ministry of Economic Affairs, Agriculture and Innovation Postbus 9102, 6700 Hc Wageningen, Nederland
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Norwegian Institute for Agricultural and Environmental Research,
Plant Health and Plant Pro tection Division
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- Instituto Nacional de Investigação Agrária e Veterinária-UEIS-SAFSV
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- Институт за шумарство, Одељење за заштиту шума
  Institute of Forestry, Department of Forest Protection Kneza Višeslava 1
  11030 Belgrade, Serbia www.forest.org.rs
- Institut za nizijsko šumarstvo i životnu sredinu, Zaštita šuma
  Institute of Lowland Forestry and Environment, Forest Protection Antona Čehova 13,
  21000 Novi Sad, Serbia
  www.ilfe.org

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Switzerland:
Eidg. Forschungsanstalt für Wald, Schnee und Landschaft (WSL)
Competence Center of Forest Protection (WSL)
http://www.wsl.ch/dienstleistungen/waldschutz/index_EN

Turkey:
- Çankırı Karatekin Üniversitesi, Fen Fakültesi, Biyoloji Bölümü, Çankırı, Türkiye
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- Tree Health Diagnostic & Advisory Service, Forest Research, Alice Holt Lodge, Wrecclesham, Farnham, Surrey GU10 4LH; ddas.ah@forestry.gsi.gov.uk

Management and control

The use of healthy transplant seedlings and site selection are the most important cultural factors affecting the management of *Phytophthora* root rot. At the farm level, proper drainage is required to avoid saturated soils. Highly susceptible firs should not be planted on sites with heavy, poorly drained soils. Avoiding the use of overhead irrigation, particularly if the water is contaminated with *Phytophthora* inoculum, will prevent shoot blight.

Pruning should not be done during wet periods to enable a quick drying of the wound and a quick periderm development. Injury of the stem, for example by mechanical weed control, should be avoided since any kind of wounding increases the potential for invasion by *Phytophthora* spp. Soil fumigation is commonly used in bare root conifer nurseries to control *Phytophthora* spp., however it is not an economical practice in Christmas tree plantations or farms. Selective systemic fungicides are also used in nurseries, but fungicides are rarely effective in Christmas tree fields. In addition, from a Christmas tree grower's point of view, the practice of using fungicides in nurseries may not be beneficial since it does not cure the disease. It only suppresses the symptoms and may lead to extensive damage when asymptomatic plants are out in the field. The use of soil fumigants and other chemicals can be restricted. Please contact your national authorities to get information on the current issue on the national registration.

Quarantine recommendation

The European and Mediterranean Plant Protection Organization (EPPO) considers *P. ramorum* to be a dangerous organism. It is listed on the EPPO Alert List. For details see http://www.eppo.int/QUARANTINE/Alert_List/alert_list.htm.

In the European Union *P. ramorum* is a regulated organism according to the Commission Decision 2002/757/EU.

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Links to further information

Phytophthora in the Forests: http://forestphytophthoras.org/

P. ramorum: www.suddenoakdeath.org, http://rapra.csl.gov.uk/ www.eppo.org

Phytophthora determination keys: http://apsjournals.apsnet.org/doi/abs/10.1094/PDIS-08-11-0636

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Disease symptoms of *Phytophthora* on *Abies* spec. (true firs)

Figure 1: Disease symptoms caused by root infection of *Phytophthora cambivora* on *Abies procera* (noble fir) in Norway (1)

Left: Discolored foliage
Right: Canker extending upwards from roots resulted in flagging and resin flow

Figure 2: Row of noble fir trees killed by *Phytophthora* root rot in a test plot at Washington State University

Abies procera (noble fir) are between two rows of *Abies nordmanniana* (Nordmann fir) (2)

Photos: (1) – V. TALGØ; (2) – G. A. CHASTAGNER