

Table 1. Distribution of oak decline in the world including the oak species and biotic/abiotic factors involved in the disease

Continent	Oak species	Abiotic factors	Biotic factors	References
<i>Asia</i>				
China	<i>Q. dentate</i> <i>Q. mongolica</i> <i>Q. variabilis</i>	Drought	<i>Armillaria</i> spp. (fungus) <i>Cytospora quercinum</i> (fungus) <i>C. vinacea</i> (fungus) <i>Coryneum sinense</i> (fungus) <i>Co. songshanense</i> (fungus) <i>Cryphonectria quercus</i> (fungus) <i>Cr. quercicola</i> (fungus) <i>Cr. japonica</i> (fungus) <i>Dendrostoma quercus</i> (fungus) <i>D. donglinensis</i> (fungus) <i>D. parasiticum</i> (fungus) <i>D. qinlingense</i> (fungus) <i>D. quercinum</i> (fungus) <i>D. dispersum</i> (fungus) <i>Diatrype quercicola</i> (fungus) <i>Diplodia quercicola</i> (fungus) <i>Cyrtopistomus castaneus</i> (insect)	Zhu et al., 2012 Gottschalk & Wargo, 1997
Far East Russia	<i>Q. dentate</i> <i>Q. mongolica</i> <i>Q. robur</i>	Drought	<i>Armillaria</i> spp. (fungus) <i>Ophiostoma grandicarpum</i> (fungus) <i>O. fusiforme</i> -like (fungus) <i>O. quercus</i> (fungus) <i>Lymantria dispar</i> (insect) <i>Operophtera brunata</i> (insect)	Selochnik et al., 2015 Gottschalk & Wargo, 1997
Japan	<i>Q. serrata</i> <i>Q. mongolica</i> <i>Q. crispula</i> <i>Q. dentate</i> <i>Q. myrsinifolia</i>	Drought	<i>Armillaria</i> spp. (fungus) <i>Ophiostorna</i> spp. (fungus) <i>Raffaelea quercivora</i> (fungus) <i>Platypus quercivorus</i> (insect) <i>Bursaphelenchus parvispicularis</i> (nematode) <i>Xanthomonas arboricola</i> (bacterium)	Kamata et al., 2002 Kanzaki & Futai, 2005 Gottschalk & Wargo, 1997
Iran	<i>Q. brantii</i> <i>Q. infectoria</i> <i>Q. libani</i> <i>Q. castaneifolia</i> <i>Q. macranthera</i>	Drought Dust Cultural practices	<i>Loranthus europaeus</i> (plant/mistletoe) <i>Biscogniauxia mediterranea</i> (fungus) <i>Obolarina persica</i> (fungus) <i>Inonotus krawtzevii</i> (fungus) <i>Epicoccum nigrum</i> (fungus) <i>Chaetomium globosum</i> (fungus) <i>Immersidiscosia eucalypti</i> (fungus) <i>Kalmusia variispora</i> (fungus) <i>Petriella sordida</i> (fungus) <i>Neocamarosporium obiones</i> (fungus) <i>Sordaria fimicola</i> (fungus) <i>Paecilomyces formosus</i> (fungus) <i>Phaeoacremonium tuscanicum</i> (fungus) <i>Discula quercina</i> (fungus) <i>Armillaria mellea</i> (fungus) <i>Dematophora</i> sp. (fungus) <i>Fusarium</i> sp. (fungus) <i>Alternaria</i> spp. (fungus) <i>Phytophthora cryptogea</i> (oomycetes) <i>Pythium aphenidermatum</i> (oomycetes) <i>Megopsis scabricornis</i> (insect) <i>Osphranteria coerulescens</i> (insect) <i>Acmaeodera wethloi</i> (insect) <i>Lugubris longicollis</i> (insect) <i>Laimaphelenchus belgradiensis</i> (nematode) <i>L. hyrcanus</i> (nematode) <i>Bacillus pumilus</i> (bacterium) <i>Brenneria goodwinii</i> (bacterium) <i>Rahnella victoriana</i> (bacterium) <i>B. roseae subsp. roseae</i> (bacterium) <i>Stenotrophomonas maltophilia</i> (bacterium)	Mirabolfathy, 2013 Ghobad-Nejhad et al., 2018 Moradi-Amirabad et al., 2019 Ahmadi et al., 2019 Alidadi et al., 2019 Alidadi et al., 2020 Pourhashemi & Sadeghi, 2020 Bakhshi ganje et al., 2020
South Korea	<i>Q. mongolica</i> <i>Q. serrata</i> <i>Q. variabilis</i> <i>Q. acutissima</i> <i>Q. aliena</i> <i>Q. dentata</i>	Drought	<i>Raffaelea quercus-mongolicae</i> (fungus) <i>Phytophthora</i> spp. (as a threat)	Hyun & Choi, 2014 Nguyen et al., 2020

Turkey	<i>Q. petraea</i> <i>Q. cerris</i> <i>Q. robur</i> <i>Q. hartwissiana</i> <i>Q. frainetto</i> <i>Q. vulcanica</i>	Drought	<i>Phytophthora quercina</i> (oomycetes) <i>P. citricola</i> (oomycetes) <i>P. plurivora</i> (oomycetes) <i>Pythium anandrum</i> (oomycetes)	Balci & Halmschlager, 2002 Balci & Halmschlager, 2003
Europe				
Austria	<i>Q. petraea</i> <i>Q. robur</i>	Soil/Site conditions	<i>Loranthus europaeus</i> (plant/mistletoe) <i>Ceratocystis</i> spp. (fungus) <i>Phytophthora quercina</i> (oomycetes) <i>P. citricola</i> (oomycetes)	Berger & Glatzel, 1994 Gottschalk & Wargo, 1997
Belgium Netherlands	<i>Q. petraea</i> <i>Q. robur</i>	Drought Excess moisture Frost damage	<i>Armillaria</i> spp. (fungus) <i>Verticillium</i> sp. (fungus) <i>Agrilus biguttatus</i> (insect) <i>Operophtera brumata</i> (insect)	Vansteenkiste et al., 2004 Losseau et al., 2020 Oosterbaan & Nabuurs, 1991 Gottschalk & Wargo, 1997
Bulgaria	<i>Q. cerris</i>	Drought	<i>Armillaria</i> spp. (fungus) <i>Ganoderma</i> (fungus) <i>Diplodia mutila</i> (fungus) <i>Hypoxyylon mediterraneum</i> (fungus)	Alexandrov & Rosnev, 1992 Gottschalk & Wargo, 1997
Czech Republic Slovakia	<i>Q. cerris</i> <i>Q. petraea</i> <i>Q. robur</i>	Drought Air pollution	<i>Loranthus europaeus</i> (plant/mistletoe) <i>Ophiostoma</i> spp. (fungus) <i>Diaporthe fasciculata</i> (fungus) <i>Ceratocystis fagacearum</i> (fungus) <i>Agrilus</i> spp. (insect)	Dolezal et al., 2010 Saniga et al., 2014 Gottschalk & Wargo, 1997
Finland	<i>Q. robur</i>	Drought	-	Sohar et al., 2014
France	<i>Q. ilex</i> <i>Q. petraea</i> <i>Q. pubescens</i> <i>Q. robur</i> <i>Q. suber</i>	Drought Frost damage Soil/Site factors Off-Site planting	<i>Collybia fusipes</i> (fungus) <i>Armillaria</i> spp. (fungus) <i>Ceratocystis</i> spp. (fungus) <i>Ophiostoma</i> spp. (fungus) <i>Collybia fusipes</i> (fungus) <i>Erysiphe alphitoides</i> (fungus) <i>Erysiphe quercicola</i> (fungus) <i>Phytophthora cinnamomi</i> (oomycetes) <i>Agrilus</i> spp. (insect) <i>Platypus cylindrus</i> (insect)	Delatour & Morelet, 1991 Gottschalk & Wargo, 1997
Germany	<i>Q. petraea</i> <i>Q. robur</i> <i>Q. rubra</i>	Drought Frost damage Excess nitrogen	<i>Armillaria</i> spp. (fungus) <i>Ophiostoma (Ceratocystis)</i> spp. (fungus) <i>Collybia fusipes</i> (fungus) <i>Microsphaera alphitoides</i> (fungus) <i>Phytophthora</i> spp. (oomycetes) <i>Agrilus biguttatus</i> (insect) <i>Operophtera brumata</i> (insect) <i>Tortrix viridana</i> (insect) <i>Emaravirus</i> (virus)	Falck, 1918 Hartmann et al., 1991 Thomas et al., 2002 Bandte et al., 2020 Gottschalk & Wargo, 1997
Switzerland	<i>Q. robur</i> <i>Q. petraea</i> <i>Q. cerris</i> <i>Q. pubescens</i> <i>Q. rubra</i>	Drought followed by a high frost	<i>Amphiportha leiphaemia</i> (fungus) <i>Pezicula cinnamomea</i> (fungus) <i>Phomopsis quercella</i> (fungus) <i>Fusarium</i> sp. (fungus) <i>Dichomera saubinetii</i> (fungus) <i>Colpoma quercinum</i> (fungus) <i>Brenneria goodwinii</i> (bacterium) <i>Gibbsiella quercinecans</i> (bacterium) <i>Rahnella victoriana</i> (bacterium)	Sieber et al., 1995 Ruffner et al., 2020
Serbia	<i>Q. robur</i> <i>Q. cerris</i>	Drought Inappropriate forest management	-	Cater et al., 2008 Stojanovic et al., 2015a Stojanovic et al., 2015b
Croatia	<i>Q. ilex</i> <i>Q. cerris</i> <i>Q. pubescens</i>	Drought	<i>Biscogniauxia mediterranea</i> (fungus) <i>Brenneria goodwinii</i> (bacteria) <i>Gibbsiella quercinecans</i> (bacteria) <i>Lonsdalea britannica</i> (bacteria) <i>Agrilus sulcicolis</i> (insect) <i>A. olivicolor</i> (insect)	Prpic & Raus, 1987 Diminic et al., 2019 Pernek et al., 2022
Greece	<i>Q. coccifera</i>	-	<i>Diplodia corticola</i> (fungus)	Tsopelas et al., 2010
Slovenia	<i>Q. robur</i>	Drought	-	Cater et al., 2008 Cater, 2015
Hungary	<i>Q. petraea</i> <i>Q. robur</i> <i>Q. cerris</i>	Drought Excess moisture Frost damage Soil/Site conditions	<i>Armillaria</i> spp. (fungus) <i>Ceratocystis fagacearum</i> (fungus) <i>Ophiostoma</i> spp. (fungus) <i>Collybia fusipes</i> (fungus) <i>Verticillium dahliae</i> (fungus) <i>Agrilus</i> spp. (insect)	Misik et al., 2013 Gottschalk & Wargo, 1997
Latvia	<i>Quercus robur</i>	Drought	<i>Brenneria goodwinii</i> (bacteria) <i>Gibbsiella quercinecans</i> (bacteria)	Matisons et al., 2013 Zalkalns & Celma, 2021

Moldavia	<i>Q. ineretina</i>	Drought	<i>Armillaria</i> spp. (fungus)	Lobanov & Rozkov, 1972
Ukraine	<i>Q. longipes</i>	Silvicultural manipulations	<i>Ophiostoma</i> spp. (fungus)	Gottschalk & Wargo, 1997
Western Russia	<i>Q. petraea</i> <i>Q. robur</i>		<i>Agrilus</i> spp. (insect)	
Poland	<i>Q. robur</i>	Drought Frost damage	<i>Armillaria</i> spp. (fungus) <i>Ceratocystis</i> spp. (fungus) <i>Fusicoccum quercus</i> (fungus) <i>Ophiostoma</i> spp. (fungus) <i>Tortrix viridana</i> (insect) Defoliation (insect)	Siwecki & Ufnalski, 1998 Gottschalk & Wargo, 1997
Sweden	<i>Q. robur</i>	Drought	<i>Phytophthora quercina</i> (oomycetes) <i>P. cactorum</i> (oomycetes) <i>P. cambivora</i> (oomycetes) Defoliation - insect	Sonesson, 1999
Italy	<i>Q. cerris</i> <i>Q. fainetto</i> <i>Q. ilex</i> <i>Q. pubescens</i> <i>Q. robur</i> <i>Q. suber</i>	Drought	<i>Armillaria</i> spp. (fungus) <i>Apiognomonina quercina</i> (fungus) <i>Colpoma quercinum</i> (fungus) <i>Collybia fusipes</i> (fungus) <i>Ganoderma</i> (fungus) <i>Diplodia mutila</i> (fungus) <i>Diplodia corticola</i> (fungus) <i>Hypoxylon mediterraneum</i> (fungus) <i>Phomopsis quercina</i> (fungus) <i>Stuartella formosa</i> (fungus) <i>Phytophthora cinnamomi</i> (oomycetes) <i>P. quercina</i> (oomycetes) <i>P. pseudocryptogea</i> (oomycetes) <i>P. tyrrhenica</i> (oomycetes) <i>P. gonapodyides</i> (oomycetes) <i>P. psychrophila</i> (oomycetes) <i>P. syringae</i> (oomycetes) <i>Bursaphelenchus eremus</i> (nematode) Defoliation - insects	Ragazzi et al., 1989 Seddaiu et al., 2020 Gottschalk & Wargo, 1997
Portugal	<i>Q. suber</i> <i>Q. cerris</i> <i>Q. ilex</i>	Drought Cultural practices	<i>Armillaria</i> spp. (fungus) <i>Hypoxylon mediterraneum</i> (fungus) <i>Diplodia corticola</i> (fungus) <i>Brenneria goodwinii</i> (bacterium) <i>Phytophthora cinnamomi</i> (oomycetes) <i>Platypus cylindrus</i> (insect) <i>Laimaphelenchus heidelbergi</i> (nematode)	Brasier et al., 1993 Maleita et al., 2015 Fernandes et al., 2022 Gottschalk & Wargo, 1997
Spain	<i>Q. canariensis</i> <i>Q. faginea</i> <i>Q. ilex</i> <i>Q. pyrenaica</i> <i>Q. suber</i> <i>Q. lusitanica</i>	Drought	<i>Diplodia mutila</i> (fungus) <i>Diplodia corticola</i> (fungus) <i>Hypoxylon mediterraneum</i> (fungus) <i>Armillaria</i> spp. (fungus) <i>Biscogniauxia mediterranea</i> (fungus) <i>Phomopsis</i> sp. (fungus) <i>Apiognomonina errabunda</i> (fungus) <i>Cryptospora quercis</i> (fungus) <i>Coryneum</i> spp. (fungus) <i>Phytophthora cinnamomi</i> (oomycetes) <i>P. quercina</i> (oomycetes) <i>P. psychrophila</i> (oomycetes) <i>P. plurivora</i> (oomycetes) <i>Platypus cylindrus</i> (insect) <i>Tortrix viridana</i> (insect) <i>Lymantria dispar</i> (insect) <i>Malacosoma neustria</i> (insect) <i>Periclista Andrei</i> (insect) <i>Lonsdalea iberica</i> (bacterium) <i>Gibbsiella quercinecans</i> (bacterium)	Gallego et al., 1999 Perez-Sierra et al., 2013 Gottschalk & Wargo, 1997 Gallego et al., 1999 Perez-Sierra et al., 2013 Gottschalk & Wargo, 1997
United Kingdom	<i>Q. petraea</i> <i>Q. robur</i> <i>Q. cerris</i> <i>Q. fabri</i>	Drought Frost damage	<i>Armillaria</i> spp. (fungus) <i>Pezicula</i> sp. (fungus) <i>Botryosphaeria stevensii</i> (fungus) <i>Fusarium solani</i> (fungus) <i>Neonectria</i> spp. (fungus) <i>Agrilus biguttatus</i> / <i>Agrilus</i> spp. (insect) <i>Brenneria goodwinii</i> (bacterium) <i>Gibbsiella quercinecans</i> (bacterium) <i>Erwinia billingiae</i> (bacterium) <i>Rahnella victoriana</i> (bacterium) <i>Lonsdalea britannica</i> (bacterium) <i>Pseudomonas taxon fulva-like</i> (bacterium)	Gibbs & Greig, 1997 Denman et al., 2010 Denman et al., 2014 Denman et al., 2017 Denman et al., 2022 Brown et al., 2017 Gottschalk & Wargo, 1997

Romania	<i>Q. cerris</i> <i>Q. frainetto</i> <i>Q. pedunculiflora</i> <i>Q. petraea</i> <i>Q. pubescens</i> <i>Q. robur</i>	Drought Soil/Site conditions	<i>Armillaria</i> spp. (fungus) <i>Ophlostoma</i> spp. (fungus) Defoliation (insect)	Simonca & Taut, 2010 Gottschalk & Wargo, 1997
America				
North America				
Western United States	<i>Q. douglasii</i> <i>Q. agrifolia</i> <i>Q. lobato</i> <i>Q. engelmannii</i> <i>Q. kelloggii</i> <i>Q. palustris</i> <i>Q. rubra</i>	Drought Excess moisture Air pollution	<i>Phoradendron villosum</i> (plant/mistletoe) <i>Armillaria</i> spp. (fungus) <i>Diplodia quercina</i> (fungus) <i>Cryptocline cinerescens</i> (fungus) <i>Discula quercina</i> (fungus) <i>Ceratocystis fagacearum</i> (fungus) <i>Phytophthora cinnamomi</i> (oomycetes) <i>Phytophthora ramorum</i> (oomycetes) <i>Agrilus</i> spp. (insect) <i>Lymantria dispar</i> (insect) <i>Gibbsiella greigii</i> (bacterium) <i>Lonsdalea quercina</i> (bacterium)	Bendixsen et al., 2015 Gottschalk & Wargo, 1997
Eastern United States	<i>Q. alba</i> <i>Q. coccinea</i> <i>Q. ellipsoidalis</i> <i>Q. palustris</i> <i>Q. prinus</i> <i>Q. rubra</i> <i>Q. velutina</i> <i>Q. falcata</i> , <i>Q. laurifolia</i> <i>Q. marilandica</i> <i>Q. nigra</i> , <i>Q. phellos</i> <i>Q. stellate</i> <i>Q. uehlenbergii</i>	Drought Excess moisture Air pollution	<i>Armillaria</i> spp. (fungus) <i>Hypoxylon atropunctatum</i> (fungus) <i>Biscogniauxia mediterranea</i> (fungus) <i>Botryosphaeria obtuse</i> (fungus) <i>Discula quercina</i> (fungus) <i>Phytophthora cinnamomi</i> (oomycetes) <i>Agrilus bilineatus</i> (insect) <i>Enaphalodes rufulus</i> (insect)	Bendixsen et al., 2015 Gottschalk & Wargo, 1997
Canada	<i>Q. alba</i> <i>Q. coccinea</i> <i>Q. rubra</i> <i>Q. macrocarpa</i>	Drought	<i>Armillaria</i> spp. (fungus) <i>Agrilus</i> spp. (insect)	Catton et al., 2007 Gottschalk & Wargo, 1997
Mexico	<i>Q. glaucooides</i> <i>Q. peduncularis</i> <i>Q. salicifolia</i> <i>Q. affinis</i>	Drought Air pollution	<i>Phoradendron villosum</i> (plant/mistletoe) <i>Hypoxylon</i> spp (fungus) <i>Ganoderma</i> spp. (fungus) <i>Armillaria</i> sp. (fungus) <i>Apiognomonium quercina</i> (fungus) <i>Phytophthora cinnamomi</i> (oomycetes) <i>Pythium</i> sp. (oomycetes) <i>Andricus quercuslaurinus</i> (insect) Overgrazing	Tainter et al., 2000
South America				
Colombia	<i>Q. humboldtii</i>	Drought	Hemiparasitic plants <i>Phialophora</i> sp. (fungus) <i>Pestalotia</i> sp. (fungus) <i>Dothiorella</i> sp. (fungus) Defoliation (insect) Nematode	Ramirez Corea, 1988
Africa				
Morocco Tunisia Algeria	<i>Q. suber</i> <i>Q. ilex</i>	Drought	<i>Hypoxylon mediterraneum</i> (fungus) <i>Biscogniauxia mediterranea</i> (fungus) <i>Botryosphaeria corticola</i> (fungus) <i>Ophiostoma quercus</i> (fungus) <i>O. stenoceras</i> (fungus) <i>Phytophthora</i> spp. (oomycetes) <i>Ceramhyx</i> beetles (insect) <i>Platypus cylindrus</i> (insect) Human impact Overgrazing	Kim et al., 2017 Kim et al., 2017 Belhoucine et al., 201 Gottschalk & Wargo, 1997

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