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Wild plant species as subjects in O_3 research

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Abstract

Tropospheric ozone (O_3) occurs in high concentrations nowadays and affects a many plant species in Northern hemisphere. Numerous wild plant species are known to be negatively affected by O_3, and this may impact biodiversity and ecosystems in near future. Given the importance of O_3 research with wild plants, we provide a list of 473 relevant taxa - that have been used as a subject of O_3 research - as a research material, under various controlled-environment facilities, along with information about their response to O_3. In addition, we include species which have been reported that they had developed ozone-like (but not confirmed) symptoms. This list of taxa along with the references is considered an important database, useful to researchers when planning their relevant investigations.

Key words: Air pollution, Biodiversity conservation, Genetic resources, Native plants, Natural heritage

Introduction

Ground-surface ozone (O_3) is an allotropic form of oxygen and a natural constitute of the atmosphere already known since the Hellenic antiquity (e.g. Saitanis 2008). The tropospheric O_3 column accounts for only 10 % of the vertical O_3 column above the earth surface (Krupa and Manning 1988) and results mainly from complex reactions among volatile organic compounds (VOCs), and NOy including nitrogen oxides (NOx,), under ultraviolet (UV) radiation (Krupa and Manning 1988, Chameides *et al*. 1994, Heo *et al*. 2012, Akritidis *et al*. 2014, Santurtun *et al*. 2015). Furthermore, long-range transport of O_3 accounts for its presence even in previously unpolluted regions (Akimoto 2003, Ganev *et al*. 2008, Kleanthous *et al*. 2014, Akimoto *et al*. 2015).

Since the Industrial Revolution, O_3 levels have been quite highly increased (Chameides *et al*. 1994, Akimoto 2003, Akritidis *et al*. 2014, Santurtun *et al*. 2015) and still continue increasing – especially in many cities - (Sicard *et al*. 2013, Paoletti *et al*. 2014, Dominguez-Lopez *et al*. 2015). Asia faces again nowadays very severe ozone pollution problem (Akimoto 2003, Akimoto *et al*. 2015, Feng *et al*. 2015) and it is predicted that many Asian regions will suffer from even higher levels (Takigawa 2009, Yamaji *et al*. 2008).

Ozone is not only a significant greenhouse gas (Paoletti and Manning 2007) but also a menace to plants (e.g. Saitanis 2008). It penetrates plant tissues through stomata and its deleterious effects force plants to express complex responses (Fiscus *et al*. 2005, Vaultier and Jolivet 2014) which finally lead to reduced yields and net primary productivity (Grantz *et al*. 2006, Feng *et al*. 2008, Emberson *et al*. 2009, Ainsworth *et al*. 2012). Forest tree species and other wild plants have been suffering from elevated O_3 (e.g. Long and Davis, 1991, Bortier *et al*. 2000, Burkey *et al*. 2006, Watanabe *et al*. 2007, Paoletti *et al*. 2008, Black *et al*. 2010, Watanabe *et al*. 2010a, Watanabe *et al*. 2010b, Calatayud *et al*. 2011b, Koike *et al*. 2012, Hoshika *et al*. 2013a, Hoshika *et al*. 2013b, Koike *et al*. 2013, Wang *et al*. 2015). Such an impact to wild plants threatens biodiversity and ecosystems stability and, therefore, O_3 research with such species is needed.

Based on the available scientific literature, we reviewed and provide here a catalog of wild plant species - either documented as sensitive or insensitive to O_3 -, that have been studied for their response to O_3, as base information and an important scientific tool for future research and resources management (Agathokleous *et al*. 2015). Using 195 original peer-reviewed publications dealing with O_3 effects on wild plant species, we created a list with 473 wild plant taxa (Agathokleous *et al*. 2015) which have been tested for O_3-induced effects, under various controlled-environment facilities (or techniques) as Table 1. In addition, we have traced and include species which have been reported that had developed ozone-like symptoms, but not confirmed (Table 2). We hope this database will support researchers in their experiments as well as practical land-use planners in their effort to form and develop green areas.

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Table 1. Wild species tested for ozone-induced affected parameters, under various controlled-environment facilities (or techniques). When the damage of a species is confirmed in other articles we also include the non-confirmed articles. The note "Yes" in the "Affected" column indicates that species are affected by ozone, and this is confirmed: at least ozone-induced injury appeared on the leaves, and most of the studies include several other parameters such as physiological, biochemical, etc., with the exception of 2-3 cases where other parameters were altered, even if foliar visible injury did not appear. "No" indicates that plants did not negatively respond to ozone at any of the measured parameters

Taxon		Type	Sub-Type	Affected	Reference
Genus & Species	**Family**				
Abies					
A. concolor (Gord. & Glend.) Lindl. ex Hildebrand	Pinaceae	Tree	Coniferous	Yes	Treshow and Stewart, 1973
A. religiosa (Kunth.) Schltdl. & Cham.	Pinaceae				Alvarez *et al*. 1998
Acacia					
A. aneura F. Muell. ex Benth	Fabaceae	Tree / Shrub		Yes	O'Connor *et al.* 1975
A. baileyana F. Muell.	Fabaceae	Tree / Shrub		No	O'Connor *et al.* 1975
A.brachybotrya Benth.	Fabaceae	Tree / Shrub		No	O'Connor *et al.* 1975
A. calamifolia Sweet. ex Lindl.	Fabaceae	Tree / Shrub		No	O'Connor *et al.* 1975
A. decurrens Willd.	Fabaceae	Tree / Shrub		No	O'Connor *et al.* 1975
A. elata A. Cunn. ex Benth.	Fabaceae	Tree / Shrub		Yes	O'Connor *et al.* 1975
A. floribunda Sieb.	Fabaceae	Tree / Shrub	Perennial	No	O'Connor *et al.* 1975
A.glandulicarpa Reader	Fabaceae	Tree / Shrub	Perennial	No	O'Connor *et al.* 1975
A. greggii A. Gray.	Fabaceae	Tree / Shrub	Deciduous	No	Temple, 1989
A. howittii F. Muell.	Fabaceae	Tree		Yes	O'Connor *et al.* 1975
A. Iongifolia (Andrews) Willd.	Fabaceae	Tree		Yes	O'Connor *et al.* 1975
A. iteaphylla F. Muell ex Benth.	Fabaceae	Tree / Shrub		No	O'Connor *et al.* 1975
A. jonesii F. Muell. & Maiden.	Fabaceae	Shrub		No	O'Connor *et al.* 1975
A. melanoxylon R. Br.	Fabaceae	Tree		No	O'Connor *et al.* 1975
A. microbotrya Benth	Fabaceae	Tree / Shrub		No	O'Connor *et al.* 1975
A. notabilis F. Muell.	Fabaceae	Tree / Shrub		No	O'Connor *et al.* 1975
A. pendula A. Cunn. ex. G.Don.	Fabaceae	Tree		No	O'Connor *et al.* 1975
A. podalyriaefolia A. Cunn. ex G.Don.	Fabaceae	Tree		Yes	O'Connor *et al.* 1975
A. pravissima F. Muell. ex Benth.	Fabaceae	Shrub	Evergreen	No	O'Connor *et al.* 1975
A. prominens A. Cunn. ex G.Don.	Fabaceae	Tree / Shrub		No	O'Connor *et al.* 1975
A. pruinosa A. Cunn. ex Benth.	Fabaceae	Tree / Shrub		Yes	O'Connor *et al.* 1975
A. pycnantha Benth.	Fabaceae	Trees		Yes	O'Connor *et al.* 1975
A. rhetinodes Schlecht.	Fabaceae	Shrub	Evergreen	No	O'Connor *et al.* 1975
A. saligna (Labill.) H. Wendl.	Fabaceae	Tree / Shrub		Yes	O'Connor *et al.* 1975
A. sophorae (Labill.) R. Br.	Fabaceae	Shrub		No	O'Connor *et al.* 1975
A. trineura F. Muell.	Fabaceae	Tree / Shrub		Yes	O'Connor *et al.* 1975
A. triptera Benth.	Fabaceae	Shrub		No	O'Connor *et al.* 1975
A. vestita Ker-Gawl.	Fabaceae	Tree / Shrub		No	O'Connor *et al.* 1975
A. wattsiana F. Muell. ex Benth.	Fabaceae	Tree / Shrub		No	O'Connor *et al.* 1975
Acer					

Taxon		Type	Sub-Type	Affected	Reference
Genus & Species	**Family**				
A. campestre L.	Sapindaceae	Tree	Deciduous	Yes	Bussotti *et al*. 2006; Zhang *et al*. 2001
A. grandidentatum Nutt.	Sapindaceae	Tree	Deciduous	Yes	Treshow and Stewart,1973
A. negundo L.	Sapindaceae	Tree		Yes	Treshow and Stewart,1973
A. pseudoplatanus L.	Sapindaceae	Tree	Deciduous	Yes	Benham *et al*. 2010; Orendovici *et al*. 2003; VanderHeyden *et al*. 2001; Vollenweider *et al*. 2003b
A. rubrum L.	Aceraceae	Tree	Deciduous	Yes	Samuelson, 1994; Schaub *et al*. 2003
A. saccharinum L.	Sapindaceae	Tree	Deciduous	Yes	Orendovici *et al*. 2003
Achillea					
A. millefolium L.	Asteraceae	Herb	Perennial	Yes	Scebba *et al*. 2006a, 2006b; Treshow and Stewart,1973
A. ptarmica L.	Asteraceae	Herb	Perennial	Yes	Franzaring *et al*. 2000
Actaea					
A. arguta Nutt.	Ranunculaceae	Forb	Perennial	Yes	Treshow and Stewart,1973
Actinostrobus					
A. pyramidalis Miq.	Cupressaceae	Tree	Coniferous	No	O'Connor *et al*. 1975
Aegilops					
A. geniculata Roth.	Poaceae			Yes	Bermejo *et al*. 2003
A. triuncialis L.	Poaceae			Yes	Bermejo *et al*. 2003
Agastache					
A. urticifolia (Benth.) Kuntze.	Lamiaceae	Forb	Perennial	Yes	Treshow and Stewart,1973
Agonis					
A. flexuosa (Willd.) Sweet.	Myrtaceae	Tree		Yes	O'Connor *et al*. 1975
Agropyron					
A. caninum (L.) P. Beauv.	Poaceae	Grass		Yes	Treshow and Stewart,1973
Agrostis					
A. capillaris L.	Poaceae	Grass	Perennial	Yes	Hayes *et al.* 2006; Scebba *et al*. 2006a
A. vineale Schreber.	Poaceae	Grass		Yes	Hayes *et al.* 2006
Ailanthus					
A. altissima (Mill.) Swingle.	Simaroubaceae	Tree	Deciduous	Yes	Bussotti and Ferretti, 2009; Gravano *et al*. 2003; Manning *et al*. 2002;
Alchemilla					
A. sp.	Rosaceae	Herb	Perennial	Yes	Bussotti and Ferretti, 2009
Allium					
A. acuminatum Hook.	Amaryllidaceae	Forb	Perennial	Yes	Treshow and

Taxon		Type	Sub-Type	Affected	Reference
Genus & Species	**Family**				
					Stewart,1973
A. ursinum L.	Amaryllidaceae	Forb	Perennial	Yes	Fangmeier, 1989
Alnus					
A. incana (L.) Moench.	Betulaceae	Tree		Yes	Manning and Godzik, 2004; Manning *et a*l. 2002
A. viridis (Chaix.) DC. ssp. Viridis	Betulaceae	Tree / Shrub		Yes	VanderHeyden *et al.* 2001
Ambrosia					
A. psilostachya DC.	Asteraceae	Forb	Perennial	Yes	Treshow and Stewart,1973
Amelanchier					
A. alnifolia (Nutt.) Nutt.	Rosaceae	Tree / Shrub	Deciduous	Yes	Treshow and Stewart,1973
Angelica					
A. pinnata S. Watson.	Apiaceae	Forb	Perennial	Yes	Treshow and Stewart,1973
Angophora					
A. costata (Gaertn.) Britten.	Myrtaceae	Tree		No	O'Connor *et al.* 1975
Anthoxanthum					
A. odoratum L.	Poaceae	Grass	Perennial	Yes	Dawnay and Mills, 2009; Hayes *et al*. 2006; Scebba *et al.* 2006a
Anthyllis					
A. cornicina L.	Fabaceae			No	Bermejo *et al*. 2003
A. lotoides L.	Fabaceae			No	Bermejo *et al*. 2003
A. vulneraria L.	Fabaceae	Medical plant	Perennial	Yes	Scebba *et al.* 2006a
Arabidopsis					
A. thaliana (L.) Heynh.	Brassicaceae			Yes	Hoepflinger *et al*. 2011
Arabis					
A. petraea	Brassicaceae	Forb		Yes	Hayes *et al.* 2006
Araucaria					
A. heterophylla (Sailsb.) Franco.	Araucariaceae	Tree	Coniferous	Yes	O'Connor *et al.* 1975
Arbutus					
A. unedo L.	Ericaceae	Tree / Shrub	Evergreen	No	Paoletti, 2005
Armeria					
A. maritima (Mill.) Willd.	Plumbaginaceae	Forb		Yes	Hayes *et al.* 2006
Artemesia					
A. tridentata Nutt.	Asteraceae	Shrub	Evergreen	Yes	Treshow and Stewart,1973
Asclepias					
A. exaltata L.	Apocynaceae			Yes	Burkey *et al*. 2006; Chappelka *et al*. 1997;Souza *et al.* 2006

Taxon		Type	Sub-Type	Affected	Reference
Genus & Species	**Family**				
A. incarnata L.	Apocynaceae	Herb	Perennial	Yes	Orendovici *et al*. 2003
A. syriaca L.	Apocynaceae			Yes	Bennett *et al*. 2006; Davis and Orendovici, 2006; Yuska *et al*. 2003
Asimina					
A. triloba (L.) Dunal.	Annonaceae	Tree / Shrub	Deciduous	Yes	Orendovici *et al*. 2003
Aster					
A. engelmannii (Eat.) A.Gray	Asteraceae	Forb	Perennial	Yes	Treshow and Stewart,1973
Astrantia					
A. major L.	Apiaceae	Herb	Perennial	Yes	Bussotti and Ferretti, 2009; Manning and Godzik 2004; Manning *et al*. 2002
Avena					
A. barbata (L.) Pott. ex Link.	Poaceae	Herb	Annual or perennial	Yes	Bermejo *et al*. 2003; Scebba *et al*. 2006a
A. sterilis L.	Poaceae			Yes	Bermejo *et al*. 2003
Banksia					
B. ericifolia L.f.	Proteaceae	Shrub		Yes	O'Connor *et al.* 1975
B. marginata Cav.	Proteaceae	Shrub		Yes	O'Connor *et al.* 1975
B. spinulosa var. *collina (*R. Br.) A.S. George	Proteaceae	Shrub		Yes	O'Connor *et al.* 1975
Betula					
B. ermanii Cham.	Betulaceae	Tree		Yes	Hoshika *et al*. 2013a
B. papyrifera Marshall.	Betulaceae	Tree		Yes	Darbah *et al*. 2008
B. pendula Roth.	Betulaceae	Tree		Yes	Benham *et al.* 2010; Karlsson *et al*. 2003; Oksanen and Holopainen, 2001; Skelly *et al*. 1998; Slimestad *et al*. 1995; VanderHeyden *et al*. 2001; Wittmann *et al*. 2007; Zhang *et al*. 2001
B. platyphylla var. *japonica* 'Whitespire'	Betulaceae	Tree		Yes/No	Hoshika *et al*. 2013c (Yes); 2013a (No)
B. pubescens Ehrh.	Betulaceae	Tree	Deciduous	Yes	Paakkonen *et al*. 1997
Biserrula					
B. pelecinus L.	Fabaceae			Yes	Bermejo *et al*. 2003
Brachychiton					
B. populneus (Schott. & Endl.) R. Br.	Malvaceae	Tree		No	O'Connor *et al.* 1975
Brassica					
B. campestris L.	Brassicaceae			Yes	Black *et al*. 2012
Briza					
B. maxima L.	Poaceae	Grass	Annual or perennial	Yes	Bermejo *et al*. 2003; Scebba *et al*. 2006a

Taxon		Type	Sub-Type	Affected	Reference
Genus & Species	**Family**				
Bromus					
B. briziformis Fisch. & C.A. Mey.	Poaceae	Grass	Annual	Yes	Treshow and Stewart,1973
B. carinatus Hook. & Am.	Poaceae	Grass	Perennial	Yes	Treshow and Stewart,1973
B. erectus Huds.	Poaceae	Grass	Perennial	Yes	Nussbaum *et al*. 2001; Scebba *et al*. 2006a
B. hordeaceus L.	Poaceae	Grass	Annual or biennial	Yes	Bermejo *et al*. 2003; Scebba *et al*. 2006a
B. sterilis L.	Poaceae			Yes	Bermejo *et al*. 2003
B. tectorum L.	Poaceae	Grass	Annual	Yes	Treshow and Stewart,1973
Buddleia					
B. davidii Franch.	Scrophulariaceae	Shrub		Yes	Fidley *et al*. 1997
Caesalpinia					
C. echinata Lam.	Fabaceae	Tree		Yes	Moraes *et al*. 2006
Callistemon					
C. salignus Sm. Sweet.	Myrtaceae	Tree / Shrub		No	O'Connor *et al.* 1975
Callitris					
C. collumellaris F. Muell.	Cupressaceae	Tree	Coniferous	No	O'Connor *et al.* 1975
C. rhomboidea R. Br. ex Rich. & A. Rich.	Cupressaceae	Tree	Coniferous	No	O'Connor *et al.* 1975
Calochortus					
C. nuttallii Torr. & A. Gray.	Liliaceae	Forb	Perennial	Yes	Treshow and Stewart,1973
Calothamnus					
C. sanguineus Labill.	Myrtaceae	Tree / Shrub		No	O'Connor *et al.* 1975
Campanula					
C. rotundifolia L.	Campanulaceae	Forb		No	Hayes *et al*. 2006
C. spp.	Campanulaceae			Yes	Skelly *et al*. 1998
Campsis					
C. radicans Seem.	Bignoniaceae	Vine	Deciduous	Yes	Oredovici *et al*. 2003
Carex					
C. demissa Hornem.	Cyperaceae	Sedge		Yes	Hayes *et al*. 2006
C. echinata Murray.	Cyperaceae	Sedge		Yes	Hayes *et al*. 2006
C. laevigata Sm.	Cyperaceae	Sedge		No	Hayes *et al*. 2006
C. nigra (L.) Reichard.	Cyperaceae	Sedge		Yes	Franzaring *et al*. 2000; Scebba *et al*. 2006a
C. panicea L.	Cyperaceae	Sedge		Yes	Hayes et al. 2006
C. siccata Dewey.	Cyperaceae	Forb	Perennial	Yes	Treshow and Stewart,1973
Carpinus					
C. betulus L.	Betulaceae	Tree		Yes	Benham *et al*. 2010; Gunthardt-Goerg *et al*. 2000
Casuarina					
C. cristata Miq.	Casuarinaceae	Tree		No	O'Connor *et al.* 1975

Taxon		Type	Sub-Type	Affected	Reference
Genus & Species	**Family**				
C. cunninghamiana Miq.	Casuarinaceae	Tree	Evergreen	No	O'Connor *et al.* 1975
C. glauca Sieber.	Casuarinaceae	Tree		No	O'Connor *et al.* 1975
C. meulleriana Miq.	Casuarinaceae	Tree		No	O'Connor *et al.* 1975
C. stricta Dryand.	Casuarinaceae	Tree	Evergreen	Yes	O'Connor *et al.* 1975
C. torulosa Dryand.	Casuarinaceae	Tree		No	O'Connor *et al.* 1975
Catalpa					
C. speciosa (Warder.) Warder. ex Engelm.	Bignoniaceae	Tree	Deciduous	Yes	Orendovici *et al*. 2003
Centaurea				Yes	Bussotti and Ferretti, 2009
C. jacea L.	Asteraceae	Herb	Perennial	Yes	Francini *et al*. 2008; Nussbaum *et al*. 2001; Ramo *et al*. 2006
C. nigra L.	Asteraceae	Forb	Perennial	Yes	Manning and Godzik, 2004; Manning *et al*. 2002
C. scabiosa L.	Asteraceae	Forb	Perennial	Yes	Manning and Godzik, 2004; Manning *et al*. 2002
Ceratonia					
C. siliqua L.	Fabaceae	Tree / Shrub	Evergreen	Yes	Orendovici *et al*. 2003; Ribas *et al*. 2005
Cercis					
C. canadensis L.	Fabaceae	Tree / Shrub	Deciduous	Yes	Orendovici *et al*. 2003
Chenopodium					
C. fremontii S. Wats.	Amaranthaceae	Forb	Annual	Yes	Treshow and Stewart, 1973
C. spp.	Amaranthaceae	Herb	Annual/perennial	Yes	Skelly *et al*.1998
Chilopsis					
C. linearis (Cav.) Sweet.	Bignoniaceae	Tree / Shrub		No	Temple, 1989
Cichorium					
C. intybus L.	Asteraceae	Forb	Perennial	Yes	Treshow and Stewart, 1973
Cinnamomum					
C. camphora (L.) J. Presl.	Lauraceae	Tree	Evergreen	Yes/No	O'Connor *et al.* 1975 (No); Zhang *et al*. 2012 (Yes)
Cirsium					
C. arvense (L.) Scop.	Asteraceae	Forb	Perennial	No/Yes	Hayes *et al*. 2006; Treshow and Stewart, 1973
C. dissecturm (L.) Hill	Asteraceae	Forb		Yes	Franzaring *et al*. 2000
Clematis					
C. vitalba L.	Ranunculaceae	Shrub		Yes	Bussotti and Ferretti, 2009; Manning *et al*. 2002; Orendovici *et al*. 2003

Taxon		Type	Sub-Type	Affected	Reference
Genus & Species	**Family**				
C. spp. L.	Ranunculaceae	Vine		No	Novak *et al*. 2003
Collomia					
C. linearis Nutt.	Polemoniaceae	Forb	Annual	Yes	Treshow and Stewart, 1973
Colutea					
C. arborescens L.	Fabaceae	Shrub	Deciduous	Yes	Orendovici *et al*. 2003
Conium					
C. maculatum L.	Apiaceae	Forb	Perennial	Yes	Treshow and Stewart, 1973
Corchorus					
C. olitorius L.	Malvaceae	Herb	Annual	Yes	Madkour and Laurence, 2002
Cornus					
C. alba L.	Cornaceae	Shrub	Suckering	Yes	Novak *et al*. 2003
C. sanguinea L.	Cornaceae	Shrub	Deciduous	Yes/No	Manning and Godzik, 2004 (Yes); Orendovici *et al*. 2003 (No); VanderHeyden *et al*. 2001 (No)
Corylus					
C. avellana L.	Betulaceae	Shrub	Deciduous	Yes/No	Benham *et al.* 2010 (Yes); Bussotti and Ferretti, 2009 (Yes); Manning *et al*. 2002; Zhang *et al*. 2001 (Yes); VanderHeyden *et al*. 2001 (No); Vollenweider *et al*. 2003b (Yes)
Crataegus					
C. monogyna Jacq.	Rosaceae	Shrubs / small trees		Yes	Novak *et al*. 2003; Orendovici *et al*. 2003
Cryptogamma					
C. crispa (L.) R.Br. ex Hook.	Pteridaceae	Forb		No	Hayes *et al*. 2006
Cryptomeria					
C. japonica (L.f) D. Don	Cupressaceae	Tree	Coniferous	Yes	Watanabe *et al*. 2010b
Cyclobalanopsis					
C. glauca (Thunb.) Oerst. or *C. repandifolia* (Liao.) Liao.	Fagaceae	Tree	Evergreen	Yes	Zhang *et al.* 2014; 2012
Cynosurus					
C. echinatus L.	Poaceae	Grass		Yes/No	Bermejo *et al*. 2003; Scebba *et al*. 2006a (No)
Dactylis					
D. glomerata L.	Poaceae	Grass	Perennial	Yes	Wagg *et al*. 2013
Danthonia					
D. decumbens (L.) DC.	Poaceae	Grass	Perennial	Yes	Franzaring *et al*. 2000

Taxon		Type	Sub-Type	Affected	Reference
Genus & Species	**Family**				
Descurainia					
D. californica (Gray.) O.E.Schulz	Brassicaceae	Forb	Annual	Yes	Treshow and Stewart, 1973
Dodonaea					
D. attenuata A. Cunn.	Sapindaceae	Shrub	Sapindaceae	No	O'Connor *et al.* 1975
Dryas					
D. octopetala L.	Rosaceae	Forb		Yes	Hayes *et al*. 2006
Echinacea					
E. purpurea (L.) Moench.	Asteraceae	Herb	Perennial	Yes	Szantoi *et al*. 2007
Epilobium					
E. angustifolium L. or Chamerion *angustifolium* (L.) Holub.	Onagraceae	Herb	Perennial	Yes	Skelly *et al*. 1998; Treshow and Stewart, 1973
E. hirsutum L.	Onagraceae	Forb	Perennial	Yes	Scebba *et al*. 2006a
E. montanum L.	Onagraceae	Herb	Perennial	Yes	Orendovici *et al*. 2003
E. watsoni Barbey.	Onagraceae	Forb	Perennial	Yes	Treshow and Stewart, 1973
Eriogonum					
E. heraclioides Nutt.	Polygonaceae	Forb	Perennial	Yes	Treshow and Stewart, 1973
Eriophorum					
E. angustifolium Honck.	Cyperaceae	Forb		Yes	Hayes *et al*. 2006
E. vaginatum L.	Cyperaceae	Sedge	Perennial	No	Mörsky *et al*. 2011
Eucalyptus					
E. aggregata H. Deane. et Maiden	Myrtaceae	Tree		Yes	O'Connor *et al.* 1975
E. alpina Lindl.	Myrtaceae	Tree		Yes	O'Connor *et al.* 1975
E. astringens (Maiden.) Maiden.	Myrtaceae	Tree		Yes	O'Connor *et al.* 1975
E. bosistoana F. Muell.	Myrtaceae	Tree		Yes	O'Connor *et al.* 1975
E. botryoides Sm.	Myrtaceae	Tree		No	O'Connor *et al.* 1975
E. brockwayi C. A. Gardner.	Myrtaceae	Tree		No	O'Connor *et al.* 1975
E. caesia Benth.	Myrtaceae	Tree		Yes	O'Connor *et al.* 1975
E. calophylla R. Br. ex var. *rosea* Lindl. or Corymbia calophylla (R.Br.) K.D.Hill & L.A.S. Johnson.	Myrtaceae	Tree		No	O'Connor *et al.* 1975
E. camaldulensis Dehnh.	Myrtaceae	Tree		Yes	O'Connor *et al.* 1975
E. campaspe S. Moore.	Myrtaceae	Tree		No	O'Connor *et al.* 1975
E. citriodora Hook. or *Corymbia citriodora* (Hook.) K.D. Hill & L.A.S. Johnson.	Myrtaceae	Tree	Evergreen	No	O'Connor *et al.* 1975
E. cladocalyx F. Muell, var. *nana* Hort.	Myrtaceae	Tree		No	O'Connor *et al.* 1975
E. cornuta Labill.	Myrtaceae	Tree		No	O'Connor *et al.* 1975
E. cosmophylla F. Muell.	Myrtaceae	Tree		No	O'Connor *et al.* 1975
E. crenulata Blakely & Beuzev.	Myrtaceae	Tree		No	O'Connor *et al.* 1975
E. dielsii C. A. Gardner.	Myrtaceae	Shrub	Evergreen	No	O'Connor *et al.* 1975

Taxon		Type	Sub-Type	Affected	Reference
Genus & Species	**Family**				
E. elata Dehnh.	Myrtaceae	Tree		Yes	O'Connor *et al.* 1975
E. ficifolia F. Muell. or *Corymbia ficifolia* (F. Muell.) K.D. Hill. & L.A.S. Johnson.	Myrtaceae	Tree		Yes	O'Connor *et al.* 1975
E. flocktoniae Maiden.	Myrtaceae	Tree		No	O'Connor *et al.* 1975
E. forrestiana Diels.	Myrtaceae	Tree		Yes	O'Connor *et al.* 1975
E. gardneri Maiden.	Myrtaceae	Tree		Yes	O'Connor *et al.* 1975
E. globulus Labill.	Myrtaceae	Tree	Evergreen	Yes	O'Connor *et al.* 1975
E. gomphocephala DC.	Myrtaceae	Tree		Yes	O'Connor *et al.* 1975
E. gracilis F. Muell.	Myrtaceae	Tree		No	O'Connor *et al.* 1975
E. hemiphloia var. *albens* (Benth.) Maiden.	Myrtaceae	Tree		Yes	O'Connor *et al.* 1975
E. kitsoniana (Kuehm.) Maiden	Myrtaceae	Tree		No	O'Connor *et al.* 1975
E. kondininensis Maiden et Blakely	Myrtaceae	Tree		No	O'Connor *et al.* 1975
E. largiflorens F. Muell.	Myrtaceae	Tree		Yes	O'Connor *et al.* 1975
E. leucoxylon F. Muell.	Myrtaceae	Tree		Yes	O'Connor *et al.* 1975
E. maculata Hook. or *Corymbia maculata* (Hook.) K.D. Hill. & L.A.S. Johnson.	Myrtaceae	Tree		No	O'Connor *et al.* 1975
E. melliodora A. Cunn. ex Schau.	Myrtaceae	Tree		No	O'Connor *et al.* 1975
E. nicholii Maiden et Blakely	Myrtaceae	Tree		Yes	O'Connor *et al.* 1975
E. nutans F. Muell.	Myrtaceae	Tree		Yes	O'Connor *et al.* 1975
E. occidentalis Endl.	Myrtaceae	Tree		Yes	O'Connor *et al.* 1975
E. pauciflora Sieber. ex Spreng.	Myrtaceae	Tree / Shrub		Yes	O'Connor *et al.* 1975
E. pellita F. Muell.	Myrtaceae	Tree		No	O'Connor *et al.* 1975
E. platypus Hook.	Myrtaceae	Tree		No	O'Connor *et al.* 1975
E. polyanthemos Schauer.	Myrtaceae	Tree		Yes	O'Connor *et al.* 1975
E. radiata Sieb. ex DC.	Myrtaceae	Tree		Yes	O'Connor *et al.* 1975
E. riminalis Labill.	Myrtaceae	Tree		Yes	O'Connor *et al.* 1975
E. robusta Sm.	Myrtaceae	Tree		Yes	O'Connor *et al.* 1975
E. sideroxylon A. Cunn. ex Wools var. *rosea*	Myrtaceae	Tree		No	O'Connor *et al.* 1975
E. spathulata Hook.	Myrtaceae	Tree		Yes	O'Connor *et al.* 1975
E. St. johnii R. T. Bak.	Myrtaceae	Tree		No	O'Connor *et al.* 1975
E. steedmanii C. A. Gardner.	Myrtaceae	Tree / Shrub		Yes	O'Connor *et al.* 1975
E. torquata Luehm.	Myrtaceae	Tree		Yes	O'Connor *et al.* 1975
E. viridis R. T. Bak.	Myrtaceae	Tree		Yes	O'Connor *et al.* 1975
E. websteriana Maiden.	Myrtaceae	Tree		No	O'Connor *et al.* 1975
E. woodwardii Maiden.	Myrtaceae	Tree		No	O'Connor *et al.* 1975
Eupatorium					
E. connabinum L.	Asteraceae	Herb	Perennial	Yes	Franzaring *et al*. 2000
E. perfoliatum L.	Asteraceae	Herb	Perennial	Yes	Orendovici *et al*. 2003
Euphorbia					
E. dulcis 'Chameleon'	Euphorbiaceae	Herb	Perennial	Yes	Bussotti and Ferretti,

Taxon		Type	Sub-Type	Affected	Reference
Genus & Species	**Family**				
					2009
Euphrasia					
E. kerneri Wettst.	Orobanchaceae			Yes	Bussotti and Ferretti, 2009
Fagus					
F. crenata Blume.	Fagaceae	Tree		Yes	Azuchi *et al*. 2014; Hoshika *et al*. 2012b; Watanabe *et al*. 2010a, 2012, 2013, 2014; Yamaguchi *et al*. 2007a, 2007b, 2010; Yonekura *et al*. 2001
F. sylvatica L.	Fagaceae	Tree	Deciduous	Yes	Baumgarten *et al*. 2000; Benham *et al.* 2010; Bortier *et al*. 2000; Braun *et al.* 2004, 2007; 2010; Bussotti and Ferretti, 2009; Cascio *et al*. 2010; Clark *et al*. 2000; Gerosa *et al*. 2003, 2008, 2009; Gunthardt-Goerg *et al*. 2000; Kitao *et al*. 2009; Landolt *et al*. 2000; Nikolova *et al*. 2010; Novak *et al*. 2008; Nunn *et al*. 2005a and 2005b; Olbrich *et al*. 2010; Pearson and Mansfield, 1993; Pretzsch *et al*. 2010; Stribley and Ashmore, 2002; VanderHeyden *et al.* 2001; Vollenweider *et al*. 2003b; Zhang *et al.* 2001
F. sylvatica L.	Fagaceae	Tree	Deciduous	No	Orendovici *et al*. 2003
Festuca					
F. ovina L.	Poaceae	Grass		Yes	Hayes *et al*. 2006
F. rubra L.	Poaceae	Grass		Yes	Hayes *et al*. 2006
Fragaria					
F. ovalis (Lehm.) Rydb. or *F. virginiana* Duchesne	Rosaceae	Forb	Perennial	Yes	Treshow and Stewart, 1973
F. vesca L.	Rosaceae	Herb	Perennial	Yes	Bussotti and Ferretti, 2009; Manninen *et al*. 2003
Frangula					
F. alnus Mill. or *Rhamnus frangula*	Rhamnaceae	Shrub	Deciduous	Yes	VanderHeyden *et al.*

Taxon		Type	Sub-Type	Affected	Reference
Genus & Species	**Family**				
L.					2001
Fraxinus					
F. americana L.	Oleaceae	Tree		Yes	Schaub *et al*. 2003
F. angustifolia Vahl.	Oleaceae	Tree	Deciduous	No	Orendovici *et al*. 2003
F. excelsior L.	Oleaceae	Tree	Deciduous	Yes	Benham *et al*. 2010; Bussotti and Ferretti, 2009; Gerosa *et al*. 2003, 2009; Gunthardt-Goerg *et al*. 2000; Landolt *et al*. 2000; Novak *et al*. 2003, 2005; Orendovici *et al*. 2003; Paoletti *et al*. 2008; Reiner *et al*. 1996; VanderHeyden *et al*. 2001; Zhang *et al*. 2001;
F. ornus L.	Oleaceae	Tree	Deciduous	Yes	Orendovici *et al.* 2003; Paoletti *et al*. 2010
Galium					
G. bifolium S. Wats.	Rubiaceae	Forb	Annual	Yes	Treshow and Stewart, 1973
G. saxatile L.	Rubiaceae	Forb		No	Hayes et al. 2006
Gayophytum					
G. racemosum Torrey. & A. Gray.	Onagraceae	Forb	Annual	Yes	Treshow and Stewart, 1973
Gentiana					
G. amarella (L.) Borner.	Gentianaceae	Forb	Perennial	Yes	Treshow and Stewart, 1973
G. asclepiadea L.	Gentianaceae	Forb	Perennial	Yes	Bussotti and Ferretti, 2009; Manning and Godzik, 2004; Manning *et al*. 2002
Geranium					
G. fremontii Torr. ex Gray or *G. caespitosum* E. James.	Geraniaceae	Forb	Perennial	Yes	Treshow and Stewart, 1973
G. richardsonii Fisch. & Trautv.	Geraniaceae	Forb	Perennial	Yes	Treshow and Stewart, 1973
G. spp.	Geraniaceae			Yes	Bussotti and Ferretti, 2009
Globularia					
G. nudicaulis L.	Plantaginaceae			Yes	Bussotti and Ferretti, 2009
Grecillea					
G. robusta A. Cunn. ex R.Br.	Proteaceae	Tree		Yes	O'Connor *et al*. 1975
Hakea					
H. laurina R. Br.	Proteaceae	Tree / Shrub		Yes	O'Connor *et al*. 1975
H. saligna (Andr.) Knight. or *H.*	Proteaceae	Tree / Shrub		No	O'Connor *et al*. 1975

Taxon		Type	Sub-Type	Affected	Reference
Genus & Species	**Family**				
salicifolia (Vent.) B.L. Burtt.					
H. suaveolens R. Br. or *H. drupacea* (C.F.Gaertn.) Roem. & Schult.	Proteaceae	Tree / Shrub	Evergreen	No	O'Connor *et al*. 1975
Hardenbergia					
H. violacea (Schneev.) Stearrn.	Fabaceae	Climbing	Evergreen	No	O'Connor *et al*. 1975
Hedera					
H. helix L.	Araliaceae	Vine	Evergreen	Yes	Torre *et al*. 1998
Hedysarum					
H. boreale Nutt.	Fabaceae	Forb	Perennial	Yes	Treshow and Stewart, 1973
Helianthus					
H. annuus L.	Asteraceae	Forb	Annual	Yes	Treshow and Stewart, 1973
H. hirsutus Raf.	Asteraceae	Forb	Perennial	Yes	Orendovici *et al*. 2003
Helleborus					
H. niger L.	Ranunculaceae	Evergreen	Perennial	Yes	Bussotti and Ferretti, 2009
Hibiscus					
H. syriacus L.	Malvaceae	Shrub	Deciduous	Yes	Paoletti *et al*. 2009
Hieracium					
H. pilosella L.	Asteraceae		Perennial	Yes	Scebba *et al*. 2006a
H. sp.	Asteraceae			Yes	Bussotti and Ferretti, 2009
Holcus					
H. lanatus L.	Poaceae	Grass	Perennial	Yes/No	Hayes *et al*. 2006 (No); Scebba *et al*. 2006a (Yes); Tonneijck *et al*. 2004 (Yes)
Horminum					
H. pyrenaicum L.	Lamiaceae		Perennial	Yes	Bussotti and Ferretti, 2009
Humulus					
H. lupulus L.	Cannabaceae	Vine	Perennial-Deciduous	Yes	Manning and Godzik, 2004; Manning *et al*. 2002
Hypericum					
H. perfoliatum L.	Hypericaceae	Tree / Shrub	Perennial	Yes	Orendovici *et al*. 2003; Scebba *et al*. 2006a
Iberis					
I. carnosa Willd.	Brassicaceae	Forb	Annual or perennial	Yes	Orendovici *et al*. 2003
Ilex					
I. aquifolium L.	Aquifoliaceae	Tree	Perennial	Yes	Ranford and Reiling, 2007a, 2007b
I. integra Thunb.	Aquifoliaceae	Tree	Perennial	Yes	Zhang *et al*. 2012
Impatiens					

Taxon		Type	Sub-Type	Affected	Reference
Genus & Species	**Family**				
I. parviflora DC.	Balsaminaceae	Forb	Annual	Yes	Manning and Godzik, 2004; Manning *et al*. 2002
Ipomoea					
I. nil 'Scarlet O'Hara'	Convolvulaceae			Yes	Alves *et al*. 2011; Dafre´ -Martinelli *et al*. 2011
Juncus					
J. effusus L.	Juncaceae	Forb		Yes	Hayes *et al*. 2006
J. squarrosus L.	Juncaceae	Forb		No	Hayes *et al*. 2006
J. sp.	Juncaceae	Forb	Perennial	Yes	Treshow and Stewart, 1973
Knautia					
K. arvensis (L.) Koult.	Dipsacaceae	Herb	Perennial	Yes	Nussbaum *et al*. 2001
K. spp.	Dipsacaceae			Yes	Bussotti and Ferretti, 2009
Koeleria					
K. pyramidata (Lam.) P. Beauv.	Poaceae	Grass	Perennial	Yes	Scebba *et al*. 2006a
Laburnum					
L. alpinum J. Presl.	Fabaceae	Tree	Deciduous	Yes	Bussotti and Ferretti, 2009
Lactuca					
L. seriola L.	Asteraceae	Plant	Annual or biennial	Yes	Bussotti and Ferretti, 2009
Lagunaria					
L. patersonia (Andrews.) G. Don.	Malvaceae	Tree	Evergreen	Yes	O'Connor *et al*. 1975
Lamottea					
L. dianae (Webb.) G. Lopez.	Asteraceae	Forb	Perennial	Yes	Calatayud *et al*. 2011a
Larix					
L. decidua Mill.	Pinaceae	Tree	Coniferous	Yes	Wieser *et al*. 2013; Wieser and Havranek, 1996
L. gmelinii (Rupr.) Rupr. var. *japonica*	Pinaceae	Tree		Yes	Koike *et al*. 2012
L. kaempferi (Lamb.) Carr.	Pinaceae	Tree	Coniferous	Yes	Koike *et al*. 2012; Watanabe *et al*. 2010b
Lathyrus					
L. lanzwertii Kell.	Fabaceae	Forb	Perennial	Yes	Treshow and Stewart, 1973
L. pauciflorus Fern.	Fabaceae	Forb	Perennial	Yes	Treshow and Stewart, 1973
Lemna					
L. gibba L.	Araceae	Aquatic	Free-floating	Yes	Forberg *et al*. 1987
Leptospermum					
L. laevigatum (Gaertn.) F. Muell.	Myrtaceae	Tree / Shrub		No	O'Connor *et al*. 1975
Liquidambar					
L. formosana Hance.	Hamalidaceae	Tree	Deciduous	Yes	Zhang *et al*. 2012

Taxon		Type	Sub-Type	Affected	Reference
Genus & Species	**Family**				
Liriodendron					
L. chinense (Hemsl.) Sarg.	Magnoliceae	Tree	Deciduous	Yes	Zhang *et al*. 2012
L. tulipifera L.	Magnoliaceae	Tree		Yes	Benham *et al*. 2010; Pellegrini *et al*. 2011
Lolium					
L. perenne L.	Poaceae			Yes	Hayes *et al.* 2009
L. rigidum (Gaudin.) Weiss. ex Nyman	Poaceae			Yes	Bermejo *et al*. 2003
Lonicera					
L. etrusca Santi.	Caprifoliaceae	Climbing	Deciduous perennial	Yes	Orendovici *et al*. 2003
Lotus					
L. corniculatus L.	Fabaceae	Herb	Perennial	Yes	Bussotti and Ferretti, 2009
Lychnis					
L. flos-cuculi L.	Caryophyllaceae	Herb	Perennial	Yes	Franzaring *et al*. 2000; Tonneijck *et al*. 2004
L. salicaria L.	Caryophyllaceae			Yes	Franzaring *et al*. 2000
Mahonia					
M. repens (Lindl.) G.Don.	Berberidaceae	Forb	Perennial	Yes	Treshow and Stewart, 1973
Malva					
M. parviflora L.	Malvaceae	Herb	Perennial	Yes	El-Khatib, 2003
Medicago					
M. lupulina L.	Fabaceae	Weed	Annual or biennial	No	Pfleeger *et al*. 2010
M. minima L. Bartal.	Fabaceae			Yes	Bermejo *et al*. 2003
M. sativa L.	Fabaceae	Forb	Perennial	Yes	Treshow and Stewart, 1973
Melaleuca					
M. armillaris (Sol. ex Gaertn.) Sm.	Myrtaceae	Tree / Shrub		Yes	O'Connor *et al*. 1975
M. decussata R. Br.	Myrtaceae	Tree / Shrub		No	O'Connor *et al*. 1975
M. ericifolia Sm.	Myrtaceae	Tree / Shrub		Yes	O'Connor *et al*. 1975
M. halmaturorum Miq.	Myrtaceae	Tree / Shrub		Yes	O'Connor *et al*. 1975
M. hypericifolia Sm.	Myrtaceae	Shrub		Yes	O'Connor *et al*. 1975
M. incana R. Br.	Myrtaceae	Shrub		No	O'Connor *et al*. 1975
M. lanceolata Otto.	Myrtaceae	Tree / Shrub		Yes	O'Connor *et al*. 1975
M. linariijolia Smith.	Myrtaceae	Tree		No	O'Connor *et al*. 1975
M. nesophila F. Muell.	Myrtaceae	Tree / Shrub		No	O'Connor *et al*. 1975
M. squarrosa Donn. ex Sm.	Myrtaceae	Shrub	summer-flowering	No	O'Connor *et al*. 1975
M. styphelioides Sm.	Myrtaceae	Tree		No	O'Connor *et al*. 1975
M. wilsonii F. Muell.	Myrtaceae	Shrub		No	O'Connor *et al*. 1975
Melica					
M. uniflora Retz.	Poaceae	Grass	Perennial	Yes	Fangmeier, 1989

Taxon		Type	Sub-Type	Affected	Reference
Genus & Species	**Family**				
Melilotus					
M. indicus (L.) All.	Fabaceae	Herb	Annual or biennial	Yes	El-Khatib, 2003
Melissa					
M. officinalis L.	Lamiaceae	Herb	Perennial	Yes	Döring *et al*. 2014
Mentha					
M. sp. L.	Lamiaceae	Herb	Perennial	Yes	Orendovici *et al.* 2003
Mertensia					
M. arizonica Greene.	Boraginaceae	Forb	Perennial	Yes	Treshow and Stewart, 1973
Mimulus					
M. guttatus DC.	Scrophulariaceae	Forb	Perennial	Yes	Treshow and Stewart, 1973
M. moschatus Dougl. ex Lindl.	Scrophulariaceae	Forb	Perennial	Yes	Treshow and Stewart, 1973
Mitella					
M. guttatus DC.	Saxifragaceae	Forb	Perennial	Yes	Treshow and Stewart, 1973
Molinia					
M. caerulea (L.) Moench.	Poaceae	Herb	Perennial	Yes	Franzaring *et al*. 2000; Tonneijck *et al*. 2004
Morus					
M. nigra L.	Moraceae	Tree	Deciduous	Yes	Skelly *et al*. 1998; VanderHeyden *et al.* 2001; Zhang *et al*. 2001
Myoporum					
M. insulare R. Br.	Scrophulariaceae	Tree / Shrub		No	O'Connor *et al*. 1975
Myrtus					
M. communis L.	Myrtaceae	Tree / Shrub	Evergreen	No	Orendovici *et al*. 2003
Nardus					
N. stricta L.	Poaceae	Grass		Yes	Hayes *et al*. 2006
Narthecium					
N. ossifragum (L.) Huds.	Nartheciaceae	Forb		No	Hayes *et al*. 2006
Neolitsea					
N. sericea (Blume.) Koidzumi.	Lauraceae	Tree		Yes	Zhang *et al*. 2012
Oenothera					
O. japonica L.	Onagraceae	Herb	Perennial	Yes	Skelly *et al*. 1998
Ornithopus					
O. compressus L.	Fabaceae			No	Bermejo *et al*. 2003
Osmorhiza					
O. occidentalis (Nutt.) Torr.	Apiaceae	Forb	Perennial	Yes	Treshow and Stewart, 1973
Oxalis					

Taxon		Type	Sub-Type	Affected	Reference
Genus & Species	**Family**				
O. acetosella L.	Oxalidaceae	Forb		Yes	Hayes *et al*. 2006
Oxyria					
O. digyna (L.) Hill.	Polygonaceae	Forb		No	Hayes *et al*. 2006
Parthenocissus					
P. quinquefolia (L.) Planch.	Vitaceae	Vine	Deciduous	Yes	Manning and Godzik, 2004; Orendovici *et al*. 2003
Pastinaca					
P. sativa L.	Apiaceae	Vegetable	Biennial	Yes	Bussotti and Ferretti, 2009
Paxistima					
P. myrsinites (Pursh.) Raf.	Celastraceae	Shrub	Perennial	Yes	Treshow and Stewart, 1973
Phacelia					
P. heterophylla Pursh.	Boraginaceae	Forb	Perennial	Yes	Treshow and Stewart, 1973
Phleum					
P. alpinum L.	Poaceae	Grass	Perennial	Yes	Danielsson *et al*. 1999
P. pratense L.	Poaceae	Grass	Perennial	Yes	Danielsson *et al*. 2013;1999
Photinia					
Photinia x fraseri 'Red Robin'	Rosaceae	Shrub	Evergreen	Yes	Zhang *et al*. 2012
Picea					
P. abies (L.) H. Karst.	Pinaceae	Tree	Coniferous	Yes	Braun *et al*. 2004; Hofer *et al.* 2008; Karlsson *et al*. 2004; Kivimaenpaa *et al*. 2004; Landolt *et al*. 2000; Magel *et al.* 1990 ; Muller *et al*. 1996; ; Nikolova *et al*. 2010; Nunn *et al*. 2005b; Ogner, 1993; Percy *et al*. 2009; Pretzsch *et al*. 2010; Siefermann-Harms *et al*. 2005; Thomas *et al*. 2005; Vollenweider *et al*. 2003b; Wieser and Havranek, 1996; Wieser *et al*. 2013;Wulff *et al*. 1996
P. abies (L.) H. Karst.	Pinaceae	Tree	Coniferous	No	Braun *et al*. 2007
P. rubens Sarg.	Pinaceae	Tree	Coniferous	Yes	Thornton *et al*. 1990
Pimpinella					
P. major (L.) Huds.	Apiaceae	Herb	Perennial	Yes	Bussotti and Ferretti, 2009
Pinus					

Taxon		Type	Sub-Type	Affected	Reference
Genus & Species	**Family**				
P. armandii Franch.	Pinaceae	Coniferous	Evergreen	Yes	Shan *et al.* 1996;1995
P. canariensis C.Sm	Pinaceae	Coniferous	Evergreen	Yes	Then et al. 2009
P. cembra L.	Pinaceae	Tree	Coniferous	Yes	Manning *et al.* 2002; Vollenweider *et al.* 2003b; Wieser *et al.* 2013
P. densiflora Sieb. et Zucc.	Pinaceae	Tree	Coniferous	Yes	Nakaji and Izuta, 2001; Nakaji *et al.* 2004; Shan *et al.* 1997; Watanabe *et al.* 2010b
P. elliotti var. Densa	Pinaceae	Tree		Yes	Evans and Fitzgerald, 1993
P. halepensis Mill.	Pinaceae	Tree		Yes	Elvira *et al.* 2007; Soda *et al.* 2000
P. ponderosa Douglas ex C. Laws.	Pinaceae	Tree		Yes	Anderson *et al.* 2003; Fares *et al.* 2010; Grulke *et al.* 1998; Temple *et al.* 1992
P. pungens Lamb.	Pinaceae	Tree	Coniferous	No	Neufeld *et al.* 2000
P. radiata D. Don	Pinaceae	Tree		Yes	Calzada *et al.* 2001
P. sylvestris L.	Pinaceae	Tree	Coniferous	Yes	Augustaitis and Bytnerowicz, 2008; Jokela *et al.* 2011; Landolt *et al.* 2000; Suorsa *et al.* 2002; Wingsle *et al.* 1992; Wulff *et al.* 1996
P. taeda L.	Pinaceae	Tree		Yes	Barbo *et al.* 2002; Horton *et al.* 1990; Kuehler and Flagler, 1999; Manning *et al.* 2003; Richardson *et al.* 1992
P. uncinata Raymond ex A. DC	Pinaceae	Tree	Pinaceae	Yes	de Quijano *et al.* 2012
P. virginiana Mill.	Pinaceae	Tree	Coniferous	No	Neufeld *et al.* 2000
Pistacia					
P. lentiscus L.	Anacardiaceae	Tree / Shrub	Evergreen	Yes	Reig-Arminana *et al.* 2004
Pittosporum					
P. phillyraeoides D.C.	Pittosporaceae	Tree / Shrub		No	O'Connor *et al.* 1975
Plantago					
P. lanceolata L.	Plantaginaceae	Forb	Perennial	Yes	Franzaring *et al.* 2000; Kolliker *et al.* 2008; Nussbaum *et al.* 2001; Scebba *et al.* 2006a; Tonneijck *et al.* 2004
P. lanceolata L.	Plantaginaceae	Forb	Perennial	No	Hayes *et al.* 2006
P. major L.	Plantaginaceae	Herb	Perennial	Yes	Black *et al.* 2010; Scebba *et al.* 2006a;

Taxon		Type	Sub-Type	Affected	Reference
Genus & Species	**Family**				
					Skelly *et al*. 1998; Zheng *et al.* 2000
P. sp. L.	Plantaginaceae	Herb		Yes	Bussotti and Ferretti, 2009; Orendovici *et al*. 2003
Poa					
P. pratensis L. Lato.	Poaceae	Grass	Perennial	Yes	Scebba *et al*. 2006a, 2006b; Treshow and Stewart, 1973
Polemonium					
P. foliosissimum A.Gray.	Polemoniaceae	Forb	Perennial	Yes	Treshow and Stewart, 1973
Polygala					
P. chamaebuxus L.	Polygalaceae			Yes	Bussotti and Ferretti, 2009
Polygonatum					
P. sp.	Asparagaceae			Yes	Bussotti and Ferretti, 2009
Polygonum					
P. douglasii Greene	Polygonaceae	Forb	Annual	Yes	Treshow and Stewart, 1973
P. sp.	Polygonaceae	Forb		Yes	Bussotti and Ferretti, 2009
Populus					
P. deltoides Bart. (ILL-129)	Salicaceae	Tree	Deciduous	Yes	Street *et al*. 2011
*P. deltoides x P. caudin*a (clone NE359)	Salicaceae	Tree	Deciduous	Yes	Wei *et al.* 2004
P. deltoides x P. nigra	Salicaceae	Tree	Deciduous	Yes	Dumont *et al*. 2013
P. deltoides x P. trichocarpa	Salicaceae	Tree	Deciduous	Yes	Reich, 1983
P. maximoviczii Henry *x berolinensis* Dippel	Salicaceae	Tree		Yes	Hoshika *et al*. 2012a, 2013b;
P. maximowiszii Henry *x P. trichocarpa* Torr. & Gray (clone NE388)	Salicaceae	Tree	Deciduous	Yes	Orendovici-Best *et al.* 2008; Wei *et al*. 2004
P. nigra L.	Salicaceae	Tree		Yes	Benham *et al*. 2010; Bortier *et al.* 2000; Gerosa *et al*. 2009; Novak *et al.* 2003, 2005
P. tremuloides Michx.	Salicaceae	Tree	Deciduous	Yes	Karnosky *et al*. 1998; Treshow and Stewart, 1973
P. trichocarpa Torr. & Gray (93-968)	Salicaceae	Tree	Deciduous	Yes	Street *et al*. 2011
P. trichocarpa Torr. & Gray *x P. deltoides* Bart (ILL-129) [F2 mapping population (Family 331)]	Salicaceae	Tree	Deciduous	Yes	Street *et al.* 2011
Potentilla					
P. erecta Uspenski ex Ledeb.	Rosaceae	Forb		Yes	Bussotti and Ferretti, 2009; Hayes *et al*. 2006

Taxon		Type	Sub-Type	Affected	Reference
Genus & Species	**Family**				
P. fruticosa L. or *Dasiphora fruticosa* (L.) Rydb.	Rosaceae	Forb	Perennial	Yes	Treshow and Stewart, 1973
Primula					
P. vulgaris Huds.	Primulaceae		Perennial	Yes	Bussotti and Ferretti, 2009
Prunus					
P. americana Marsh.	Rosaceae	Tree / Shrub		Yes	Orendovici *et al*. 2003
P. avium (L.) L.	Rosaceae	Tree	Deciduous	Yes	Novak *et al.* 2003; VanderHeyden *et al.* 2001; Zhang *et al.* 2001
P. serotina Ehrh.	Rosaceae	Tree		Yes	Benham *et al.* 2010; Bennett *et al.* 2006; Chappelka *et al*. 1997; Davis and Orendovici, 2006; Fredericksen *et al*. 1995, 1996; Ghosh *et al*. 1998; Gunthardt-Goerg *et al*. 2000; Kouterick *et al.* 2000; Lee *et al.* 1999; Long and Davis, 1991; Orendovici-Best *et al*. 2008; Samuelson, 1994; Schaub *et al*. 2003; Skelly *et al.* 1997, 1998; VanderHeyden *et al*. 2001; Vollenweider *et al*. 2003a; Yuska *et al*. 2003; Zhang *et al.* 2001, 2010
P. spinosa L.	Rosaceae	Tree			Benham *et al*. 2010; Orendovici *et al*. 2003
Psidium					
P. guajava L. 'Paluma'	Myrtaceae	Tree	Fruit	Yes	Alves *et al*. 2011; Pina and Moraes, 2010; de Rezende and Furlan, 2009; Pina and Moraes, 2007; Furlan *et al.* 2007
Quercus					
Q. faginea Lam.	Fagaceae	Tree		Yes	Calatayud *et al*. 2011b
Q. gambelii Nutt.	Fagaceae	Forb	Perennial	Yes	Treshow and Stewart, 1973
Q. ilex L.	Fagaceae	Tree		Yes	Baldantoni *et al.* 2011; Ribas *et al*. 2005
Q. ilex L. *subsp. Ballota*	Fagaceae	Tree		Yes	Calatayud *et al.* 2011b
Q. kelloggii Newb.	Fagaceae	Tree		Yes	Handley and Grulke,

Taxon		Type	Sub-Type	Affected	Reference
Genus & Species	**Family**				
					2008
Q. mongolica var. crispula Fisch. ex Ledeb.	Fagaceae	Tree		Yes	Watanabe *et al.* 2013
Q. pyrenaica Willd.	Fagaceae	Tree		Yes	Calatayud *et al.* 2011b
Q. robur L.	Fagaceae	Tree		Yes	Gerosa *et al.* 2008
Q. rubra L.	Fagaceae	Tree	Deciduous	Yes	Calatayud *et al*. 2011b; Edwards *et al.* 1994; Gerosa *et al.* 2009; Samuelson *et al.* 1996; Weinstein *et al*. 1998
Q. serrata J.A. Mur.	Fagaceae	Tree	Deciduous	Yes	Watanabe *et al*. 2007
Ranunculus					
R. acris L.	Ranunculaceae	Forb	Perennial	Yes/No	Hayes *et al*. 2006 (No); Wagg *et al*. 2013 (Yes)
R. spp.	Ranunculaceae	Forb	Perennial	Yes	Bussotti and Ferretti, 2009
Rhamnus					
R. cathartica L.	Rhamnaceae	Tree / Shrub	Deciduous	Yes	Benham *et al*. 2010; VanderHeyden *et al.* 2001; Zhang *et al.* 2001
Rhus					
R. copallinum L.	Anacardiaceae	Tree	Deciduous	Yes	Davis and Orendovici, 2006; Orendovici *et al.* 2003
R. trilobata Nutt.	Anacardiaceae	Shrub		Yes	Temple, 1989
Ribes					
R. alpinum L.	Grossulariaceae	Shrub	Deciduous	Yes	Novak *et al.* 2003
R. hudsonianum Richards.	Grossulariaceae	Shrub		Yes	Treshow and Stewart, 1973
Robinia					
R. pseudoacacia L.	Fabaceae	Tree		Yes	Benham *et al.* 2010; Bussotti and Ferretti, 2009; Vollenweider *et al*. 2003b
Rosa					
R. canina L.	Rosaceae	Shrub	Deciduous	Yes	Bussotti and Ferretti, 2009
R. woodsii Lindl.	Rosaceae	Shrub	Deciduous	Yes	Treshow and Stewart, 1973
Rubia					
R. peregrina L.	Rubiaceae	Herb	Perennial	Yes	Bussotti and Ferretti, 2009
Rubus					
R. fruticosus Aggr.	Rosaceae		Perennial	Yes	Vollenweider *et al*. 2003b

Taxon		Type	Sub-Type	Affected	Reference
Genus & Species	**Family**				
R. sp.	Rosaceae			Yes	Bussotti and Ferretti, 2009
Rudbeckia					
R. laciniata L.	Asteraceae	Herb	Perennial	Yes	Burkey *et al*. 2006; Chappelka *et al*. 2003; Davison *et al*. 2003; Szantoi *et al*. 2009
R. occidentalis Nutt.	Asteraceae	Forb	Perennial	Yes	Treshow and Stewart, 1973
Rumex					
R. acetosa L.	Polygonaceae	Forb	Perennial	No	Hayes *et al*. 2006
R. acetosa L.	Polygonaceae	Forb	Perennial	Yes	Scebba *et al.* 2006a; Manning and Godzik, 2004; Skelly *et al.* 1998
R. crispus L.	Polygonaceae	Forb	Perennial	Yes	Treshow and Stewart, 1973
R. obtusifolius L.	Polygonaceae	Weed	Perennial	Yes	Nussbaum *et al.* 2001; Scebba *et al*. 2006a; VanderHeyden *et al*. 2001
R. sanguineus L.	Polygonaceae		Perennial	Yes	Skelly *et al*. 1998
R. sp. L.	Polygonaceae	Herb	Annual or biennial or perennial	Yes	Orendovici *et al*. 2003
Salix					
S. alba L.	Salicaceae	Tree	Deciduous	Yes	Novak *et al*. 2003
S. gooddingii C.R.Ball.	Salicaceae	Tree		Yes	Temple, 1989
S. viminalis L.	Salicaceae	Shrub		Yes	VanderHeyden *et al.* 2001
Salvia					
S. pratensis L.	Lamiaceae	Herb	Perennial	Yes	Bussotti and Ferretti, 2009
Sambucus					
S. ebulus L.	Adoxaceae	Herb		Yes	Orendovici *et al*. 2003
S. melanocarpa A.Gray	Caprifoliaceae	Shrub	Deciduous	Yes	Treshow and Stewart, 1973
S. nigra L.	Adoxaceae	Tree / Shrub	Deciduous	Yes	Benham *et al.* 2010; Orendovici *et al*. 2003
S. racemosa L.	Adoxaceae	Shrub		Yes	Manning and Godzik, 2004; Manning *et al.* 2002; VanderHeyden *et al*. 2001
Sanguisorba					
S. minor Scop.	Rosaceae	Herb	Perennial	Yes	Bussotti and Ferretti, 2009
Saxifraga					
S. arguta D. Don	Saxifragaceae	Forb	Perennial	Yes	Treshow and Stewart, 1973

Taxon		Type	Sub-Type	Affected	Reference
Genus & Species	**Family**				
S. stellaris (L.) or *Micranthes stellaris* (L.) Galasso, Banfi et Soldano	Saxifragaceae	Forb		Yes	Hayes *et al*. 2006
Schima					
S. superba Gardner. et Champion.	Theaceae	Tree	Evergreen	Yes	Zhang et *al.* 2012
Scirpus					
S. cespitosus L.	Cyperaceae	Forb		Yes	Hayes *et al*. 2006
Senecio					
S. fluviatilis Wallr. or *S. ovatus* (G. Gaertn. et Al.) Willd.	Asteraceae	Forb		No	Hayes *et al.* 2006
S. subalpinus Koch.	Asteraceae	Forb	Perennial	Yes	Manning and Godzik, 2004
S. serra Hook.	Asteraceae	Forb	Perennial	Yes	Treshow and Stewart, 1973
S. vulgaris L.	Asteraceae	Forb		Yes	El-Khatib, 2003
Silphium					
S. perfoliatum L.	Asteraceae	Herb	Perennial	Yes	Orendovici *et al.* 2003
Sonchus					
S. oleraceus L.	Asteraceae			Yes	El-Khatib, 2003
Sorbus					
S. aria Crantz.	Rosaceae	Tree	Deciduous	Yes	Vollenweider *et al*. 2003b
S. aucuparia L.	Rosaceae	Tree / Shrub	Deciduous	Yes/No	Gunthardt-Goerg *et al.* 2000 (Yes); Manning and Godzik, 2004 (Yes); Manning *et al*. 2002 (Yes); Orendovici *et al*. 2003 (No)
Spartina					
S. alterniflora Loisel.	Poaceae	Grass	Perennial (Deciduous)	Yes	Taylor *et al.* 2002
Sphagnum					
S. papillosum Lindb.	Sphagnaceae	Moss		No	Mörsky *et al.* 2011
Spiraea					
S. spp.	Rosaceae	Shrub	Deciduous	Yes	Skelly *et al.* 1998
Stachys					
S. officinalis (L.) Trevis. ex Briq.	Lamiaceae	Forb (grassland)	Perennial	Yes	Manning and Godzik, 2004; Manning *et al.* 2002
S. spp.	Lamiaceae	Shrub / Herb	Annual or perennial	Yes	Bussotti and Ferretti, 2009
Succisa					
S. pratensis Moench.	Dipsacaceae		Perennial	Yes	Franzaring *et al*. 2000
Symphoricarpos					
S. vaccinioides Rydb.	Caprifoliaceae	Shrub	Deciduous	Yes	Treshow and Stewart, 1973
Taraxacum					

Taxon		Type	Sub-Type	Affected	Reference
Genus & Species	**Family**				
T. officinale F.H. Wigg.	Asteraceae	Forb	Perennial	Yes	Bussotti and Ferretti, 2009 Treshow and Stewart, 1973
Teucrium					
T. scorodonia L.	Lamiaceae	Herb	Perennial	Yes	Orendovici *et al*. 2003
Thalictrum					
T. endleri Engelm.	Ranunculaceae	Forb	Perennial	Yes	Treshow and Stewart, 1973
Thymus					
T. polytrichus A. Kern. ex Borbas	Lamiaceae	Forb		No	Hayes *et al.* 2006
Tibouchina					
T. pulchra (Cham.) Cogn.	Melastomataceae	Tree		Yes	Furlan *et al.* 2008; Moraes *et al*. 2003
Tilia					
T. cordata Miller.	Malvaceae	Tree	Deciduous	Yes	Novak *et al*. 2003
T. platyphyllos Scop.	Malvaceae	Tree	Deciduous	Yes	Novak *et al.* 2003
Toxicodendron					
T. radicans (L.) Kuntze.	Anacardiaceae	Forb	Perennial	Yes	Treshow and Stewart, 1973
Tradescantia					
T. pallida (Rose.) Hunt.	Commelinaceae		Perennial + Evergreen	Yes	de Souza Lima et al. 2009
Trifolium					
T. angustifolium L.	Fabaceae			Yes	Bermejo *et al*. 2003
T. cherleri L.	Fabaceae			Yes	Bermejo *et al*. 2003
T. ciliolatum Benth.	Fabaceae	Herb	Annual	No	Pfleeger *et al.* 2010
T. glomeratum L.	Fabaceae			Yes	Bermejo *et al*. 2003
T. hirtum All.	Fabaceae			Yes	Bermejo *et al*. 2003
T. hybridum L.	Fabaceae	Herb	Perennial	Yes	Pfleeger *et al*. 2010
T. microcephalum Pursh.	Fabaceae	Herb	Annual	No	Pfleeger *et al.* 2010
T. pratense L.	Fabaceae	Herb	Perennial	Yes	Bussotti and Ferretti, 2009; Nussbaum *et al*. 2001; Scebba *et al.* 2006a
T. repens L.	Fabaceae			Yes	Hayes *et al*. 2009; Scebba *et al*. 2006a; Tang *et al*. 1999
T. striatum L.	Fabaceae			Yes	Bermejo *et al*. 2003
T. subterraneum L.	Fabaceae		Annual	Yes	Bermejo *et al.* 2003; Sanz *et al*. 2005; Vollsnes *et al.* 2010
Trisetum					
T. flavescens (L.) P. Beauv.	Poaceae	Grass	Perennial	Yes	Nussbaum *et al*. 2001
Tristania					
T. conferta (R. Br.) Steud. or *Lophostemon confertus* (R.Br.) P.G. Wilson et J.T. Waterh.	Myrtaceae	Tree		Yes	O'Connor *et al*. 1975

Taxon		Type	Sub-Type	Affected	Reference
Genus & Species	**Family**				
Tsuga					
T. canadensis (L.) Carriere.	Pinaceae	Tree	Coniferous	No	Neufeld *et al*. 2000
Ulmus					
U. minor Mill.	Ulmaceae	Tree		Yes	Orendovici *et al*. 2003
Urtica					
U. gracilis Alton. or *U. dioica* ssp. *gracilis* (Alton.) Selander.	Urticaceae	Forb	Perennial	Yes	Treshow and Stewart, 1973
Vaccinium					
V. myrtillus L.	Ericaceae	Shrub		Yes	Bussotti and Ferretti, 2009; Manning *et al*. 2002
Verbesina					
V. occidentalis Walt.	Asteraceae	Herb	Perennial	Yes	Burkey *et al*. 2006; Chappelka *et al*. 2003
Vernonia					
V. noveboracensis Wild.	Asteraceae	Herb		Yes	Orendovici *et al*. 2003
Veronica					
V. anagallis-aquatica L.	Plantaginaceae	Forb	Perennial	Yes	Treshow and Stewart, 1973
V. chamaedrys L.	Plantaginaceae	Herbs	Perennial	Yes	Scebba *et al*. 2006a; 2006b
V. spp.	Plantaginaceae	Herb / Shrub / Small tree	Annual / perennial	Yes	Bussotti and Ferretti, 2009
Viburnum					
V. lantana L.	Adoxaceae	Shrub	Deciduous	Yes	Benham *et al*. 2010; Bussotti and Ferretti, 2009; Novak *et al*. 2003, 2005, 2008; Orendovici *et al*. 2003; Skelly *et al*. 1998; VanderHeyden *et al*. 2001; Vollenweider *et al*. 2003b; Zhang *et al*. 2001
V. lentago L.	Adoxaceae	Tree / Shrub		Yes	Orendovici *et al*. 2003
V. opulus L.	Adoxaceae	Shrub	Deciduous	Yes	Benham *et al.* 2010; Manning *et a*l. 2002; Novak *et al*. 2003
V. tinus L.	Adoxaceae	Shrub	Evergreen	No	Orendovici *et al*. 2003
Vicia					
V. americana Muhl. ex Willd.	Fabaceae	Forb	Perennial	Yes	Treshow and Stewart, 1973
V. tetrasperma (L.) Moench.	Fabaceae	Herb	Annual	No	Pfleeger *et al*. 2010
Viola					
V. adunca Sm.	Violaceae	Forb	Perennial	Yes	Treshow and Stewart, 1973

Taxon		Type	Sub-Type	Affected	Reference
Genus & Species	**Family**				
V. lutea Huds.	Violaceae	Forb		No	Hayes *et al*. 2006
V. reichenbachiana Jord. ex Boreau.	Violaceae	Herb	Perennial	Yes	Fangmeier, 1989
Vitis					
V. vinifera L.	Vitaceae			Yes	Bussotti and Ferretti, 2009; Davis and Orendovici, 2006 (*V. spp*.)
Vulpia					
V. ciliata L. Dumont.	Poaceae	Herb		Yes	Scebba *et al*. 2006a
V. myuros L. Gmelin.	Poaceae	Grass	Annual	No	Scebba *et al*. 2006a
Zelkova					
Z. serrata (Thunb.) Makino.	Ulmaceae	Tree		Yes	Hoshika *et al*. 2012c

Table 2. Species reported that have developed ozone-like (but not confirmed) symptoms. The most of them have been observed in naturally grown plants (under open-field conditions) where the influence of other factors (such as other pollutants, nutrient deficiency, etc.) cannot be excluded

Taxon		Type	Sub-Type	Foliar Visible Injury	Reference
Genus & Species	**Family**				
Chaerophyllum					
C. aromaticum L.	Apiaceae	Forb	Perennial	Yes	Manning *et al*. 2002
Cornus					
C. sanguinea L.	Cornaceae	Shrub	Deciduous	Yes	Manning *et al*. 2002
Geranium					
G. palustre L.	Geraniaceae	Forb	Perennial	Yes	Manning *et al*. 2002
Lapsana					
L. communis L.	Asteraceae	Forb	Annual	Yes	Manning *et al*. 2002
Ligustrum					
L. vulgare L	Oleaceae			Yes	Benham *et al*. 2010
Lonicera					
L. nigra L.	Caprifoliaceae	Shrub		Yes	Manning *et al*. 2002
Pinus					
P. koraiensis Sieb. et Zucc.	Pinaceae	Tree		Yes	Choi *et al*. 2006
P. rigida Miller.	Pinaceae	Tree		Yes	Choi *et al*. 2006
Populus					
P. tremula L.	Salicaceae	Tree		Yes	Benham *et al*. 2010
Prunus					
P. mahaleb L.	Rosaceae	Tree		Yes	Benham *et al*. 2010
Salix					
S. caprea L.	Salicaceae	Shrub	Deciduous	Yes	Manning *et al*. 2002
S. daphnoides Vill.	Salicaceae			Yes	Benham *et al*.

Taxon		Type	Sub-Type	Foliar Visible Injury	Reference
Genus & Species	Family				
					2010
Sassafras					
S. albidum (Nutt.) Nees.	Lauraceae	Tree	Deciduous	Yes	Davis and Orendovici, 2006
Thymus					
T. alpestris A. Kern.	Lamiaceae	Forb	Perennial	Yes	Manning *et al*. 2002
Ulmus					
U. excelsior L.	Ulmaceae	Tree		Yes	Manning *et al*. 2002
U. glabra Huds.	Ulmaceae	Tree		Yes	Benham *et al.* 2010
U. laevis Pall.	Ulmaceae	Tree		Yes	Manning *et al*. 2002
U. montana Stokes, Sm., Loudon, Mathieu, With or *U. glabra* Huds.	Ulmaceae	Tree		Yes	Manning *et al*. 2002
Vincetoxicum					
V. officinale Moench. or *Cynanchum vincetoxicum* (L.) Pers.	Apocynaceae	Forb	Perennial	Yes	Manning *et al*. 2002

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