Recent Publications

Beland, J.D., Krakowski, J., Ritland, C.E., Ritland, K, and Y.A. El-Kassaby. 2005. Genetic structure and mating system of northern *Arbutus menziesii* (Ericaceae) populations. Can. J. Bot. 83: 1581-1589.

Bergendorf, D. 2002. The influence of soil properties on the morphology and health of the Pacific madrone (*Arbutus menziesii* Pursh) in Seattle public parks. MS Thesis, University of Washington.

Cahill, A. and L. Chalker-Scott. 2001. The role of soil environment in *Arbutus menziesii* (Pacific madrone) seedling success. *American Nurseryman* 193 (8):26-34.

Chalker-Scott, L. 2008. A great tree, but a poor companion. *MasterGardener Magazine* 2(2):15-16.

Cogger, C., Hummel, R., Hart, J., and Bary, A. 2008. Soil and redosier dogwood response to incorporated and surface-applied compost. HortScience 43(7): 2143-2150.

Elliott, M., Chastagner, G. A., Coats, K. P. Sikdar, P., and Xiao, C.L. (2014). First Report of a New Leaf Blight Caused by *Phacidiopycnis washingtonensis* on Pacific Madrone (*Arbutus menziesii*) in Western Washington and Oregon. Plant Disease 98:1741.

Elliott, M., and R. L. Edmonds. 2008. Injected treatments for management of madrone canker. Arboriculture and Urban Forestry 34 (2): 110-115.

Farr, D. F., M. Elliott, and A. Y. Rossman. 2005. *Fusicoccum arbuti* sp. nov. causing cankers on Pacific madrone in western North America. Mycologia 97(3): 730-741.

Harrington, C.A. and Gould, P.J. 2015. Tradeoffs between chilling and forcing in satisfying dormancy requirements for Pacific Northwest tree species. Frontiers in Plant Science doi:10.3389/fpls.2015.00120

Lintz, H.E., Gray, A., Yost, A., Sniezko, R., Woodall, C., Reilly, M., Hutten, K., and Elliott, M.. 2016. Quantifying density-independent mortality of temperate tree species. Ecological Indicators 66:1-9.

McGregor, R.R., Sakalidis, M.L., and Hamelin, R. C. 2016. *Neofusicoccum arbuti*: a hidden threat to *Arbutus menziesii* characterized by widespread latent infections and a broad host range. Canadian Journal of Plant Pathology 38: 70-81. DOI:10.1080/07060661.2015.1135476

Niemiec, S.S., G.R. Ahrens, S. Willits, and D.E. Hibbs. 1995. HARDWOODS OF THE PACIFIC NORTHWEST. Forest Research Laboratory, Oregon State University, Corvallis. Research Contribution 8. 115 p.
http://ir.library.oregonstate.edu/xmlui/bitstream/handle/1957/7623/RC8.pdf?sequence=1
Pacific madrone chapter http://owic.oregonstate.edu/pacific-madrone-arbutus-menziesii

Beland, J.D., Krakowski, J., Ritland, C.E., Ritland, K, and Y.A. El-Kassaby. 2005. Genetic structure and mating system of northern *Arbutus menziesii* (Ericaceae) populations. Can. J. Bot. 83: 1581-1589.

Abstract

Arbutus (Arbutus menziesii Pursh. (Ericaceae)) is the only broadleaved evergreen tree native to Canada. It occurs in three red-listed (endangered) plant communities in British Columbia (BC), threatened by urban encroachment, fire suppression, grazing, and exotic invasive species. Its growth is sensitive to environmental changes: more severe summer drought caused by climate change could further threaten this species. Amplified fragment length polymorphisms (AFLPs) were assayed in 10 populations in BC and 1 in Washington to obtain baseline population genetic and mating system data. We found that genetic diversity within populations was low (mean H = 0.094) for a woody perennial. Genetic variation among populations (F_{ST} = 0.15) was comparable to woody perennials on average (0.19). Pairwise kinship coefficients were significantly associated with distance ($p < 0.01$). The multilocus outcrossing rate for one BC island population was high (t_m = 0.97), but inbreeding due to consanguineous matings was also quite high ($t_m - t_s$ = 0.10). These data can be used to guide conservation strategies and future research priorities for arbutus.

Keywords: amplified fragment length polymorphisms, *Arbutus menziesii*, genetic diversity, kinship, population structure

Bergendorf, D. 2002. The influence of soil properties on the morphology and health of the Pacific madrone (*Arbutus menziesii* Pursh) in Seattle public parks. MS Thesis, University of Washington.

Abstract

The Pacific madrone (*Arbutus menziesii*) Pursh is a favorite tree of many Seattle residents. Within recent years, individual trees have been showing significant decline in both urban and undeveloped areas of the Puget Sound region (Elliott 1999a). Urban populations of *A. menziesii* in Seattle Public Parks have shown increasing signs of disease in the last thirty years, many associated with fungal pathogens such as *Natrassia mangiferae* and *Phytopthora* species, which are major causes of decline in individual trees.

Although previous research has suggested a link between soil compaction, soil texture, and the growth and health of *A. menziesii*, the relationships between soil physical properties and the incidence of disease of *A. menziesii* trees need further investigation for a better understanding of the pattern of their decline. This research was conducted to further the scientific understanding of these relationships, and in particular, to examine the influence on tree morphology (and inferred health) of soil properties including bulk density, texture, gravel content, and hydraulic infiltration.

In June of 2000, 30 *A. menziesii* trees were selected at random from the Seattle Public Park System. Live crown ratio, the ratio of live crown height to tree height, was used to represent the health of trees and their capacity to resist biological stress. Trees studied were selected to encompass a range of live crown ratios. Twenty soil samples were taken from the root zone of each tree and assessed for soil bulk density, soil texture, and gravel content. Graphing, linear regression analysis, and analysis of variance tests were used to examine and test relationships of soil bulk density, soil texture, and gravel content, and live crown ratio of the trees selected.

No statistically significant relationship was detected between soil bulk density and live crown ratio. Although a statistically significant difference in live crown ratios was found for trees growing in soils of differing textures using analysis of variance, a Tukey's honestly significant difference test could not confirm actual differences between trees in different texture groups. However, for trees with live crown ratio measurements of < 0.61, a statistically significant difference in live crown ratios was found for trees growing in soils of differing gravel content. For these trees, higher live crown ratios were associated with soils of higher gravel contents. For trees with live crown ratios of > 0.60, however, there was not a statistically significant difference in live crown ratio for trees growing in soils of differing gravel content. Therefore, a live crown ratio of 0.60 may represent a threshold value above which certain soil properties do not significantly affect the health of trees.

Soils with high gravel content facilitate rapid soil drainage. This may buffer *A. menziesii* trees from disease in several ways. Soils with high gravel content resist compaction, allow water and air infiltration, leach excess soil nitrogen and may inhibit the spread of soil borne pathogens. Suggestions are also provided for improving root zone drainage for existing trees in situ.

Cogger, C., Hummel, R., Hart, J., and Bary, A. 2008. Soil and redosier dogwood response to incorporated and surface-applied compost. HortScience 43(7): 2143-2150.

Abstract

Although compost can improve soil properties related to plant growth and water quality, the value of amending landscape beds for trees and shrubs has been questioned. This research assesses short and midterm effects of compost application and bark mulch on soils and plants in landscape beds and compares the effects of compost applied to the surface or incorporated. Trees and shrubs were established in 2001 in a replicated field experiment with the following treatments: 1) unamended control; 2) compost (7.6-cm depth) applied to the surface; 3) 7.6 cm compost incorporated by rototilling to a depth of 20 cm; 4) bark mulch (7.6 cm); 5) compost surface-applied (7.6 cm) + bark mulch (7.6 cm); and 6) compost incorporated + bark mulch. Soil measurements were made one or more times between 2001 and 2007, including bulk density, compaction, infiltration, aggregate stability, soil moisture tension, total carbon (C) and nitrogen (N), nitrate-N, Bray-phosphorus, exchangeable potassium, and pH. Bark and compost mulch depths were determined three times and plant growth measured annually. Half the depth of surface-applied compost and 26% to 41% of the initial soil C increase from incorporated compost remained 5 years after application; and significant changes in bulk density, compaction, infiltration, and nutrients were apparent. Compost incorporation had a greater effect than surface application on soil C, N, and bulk density. Infiltration was similar in incorporated and surface treatments, and nutrient availability was similar except for N. Soil moisture retention was improved with surface-applied compost. Bark had similar effects as surface-applied compost on bulk density, soil moisture retention, and infiltration. During the first 4 years after transplanting, dogwoods in the compost incorporated + bark mulch treatment typically had larger shoot growth indices. By Year 5, treatment no longer influenced shoot growth. Plants in compost-treated plots had darker green leaves. Surface application of compost could provide significant benefits where incorporation is not feasible.

Elliott, M., Chastagner, G. A., Coats, K. P. Sikdar, P., and Xiao, C.L. (2014). First Report of a New Leaf Blight Caused by *Phacidiopycnis washingtonensis* on Pacific Madrone (*Arbutus menziesii*) in Western Washington and Oregon. Plant Disease 98:1741.

In recent years, a leaf blight disease, consisting of browned, desiccated leaves occurring mainly in the lower parts of the canopy, has been observed during wet springs on Pacific madrone (*Arbutus menziesii*) in western Washington and Oregon. In May 2009 and 2011, severe outbreaks occurred and symptomatic leaves from madrones growing in the region were sampled to determine the causal agent. Two symptoms, leaf necrosis or blotching along the edges and tips of the leaves, and leaf spot, were observed. Small segments of diseased tissue were cut from the leaves, surface-disinfected, rinsed, and plated on malt extract agar. Fifty percent of the leaf blotch and 30% of leaf spot samples yielded a fungus that was fast-growing (20 mm diameter in 4 days at 25°C) and produced colonies that were a pale gray with dark gray reverse and a felty texture. On potato dextrose agar (PDA), pycnidia formed and exuded conidia in peach-colored droplets after 2 weeks under room temperature and light conditions. Pycnidia were spherical and 12.5 to 39.8 µm, average 24.2 µm in diameter. Conidia were hyaline, ovoid, and 5.8 to 8.5 × 3.1 to 4.7 µm (average 7.0 × 3.7 µm). The fungus was identified as *Phacidiopycnis washingtonensis* based on its morphology (1). To confirm the identity, the internal transcribed spacer (ITS) region of the rDNA was amplified with ITS1/ITS4 primers (2) and sequenced (GenBank Accession Nos. JQ743784 to 86). BLAST analysis showed 100% nucleotide identity with those of *P. washingtonensis* in GenBank (AY608648). The fungus was also isolated from lesions on green shoots and the petiole and leaf blade of dead attached leaves. To test pathogenicity, 3-year-old Pacific madrone seedlings (three for each isolate) were inoculated with five isolates of the fungus and maintained in the greenhouse (25°C); the experiment was conducted twice. Five leaves from each tree were cold injured (–50°C) at a marked $5 \times 5\ mm^2$ area with a commercial aerosol tissue freezing product prior to inoculation and five leaves were not cold injured. A 5-mm-diameter mycelial plug cut from the margin of 6-day-old PDA culture was applied to the marked areas on the upper leaf surface. The inoculated area was covered with moist cheese cloth and wrapped with Parafilm. Leaves treated with blank PDA plugs served as control. Leaves were enclosed in plastic bags to maintain moisture for the first 15 h post inoculation and cheese cloths were removed after 15 days. All cold-injured inoculated leaves showed symptoms of blight starting at 2 weeks after inoculation, and no symptoms appeared on the controls. On non-cold injured inoculated leaves, only one isolate caused symptoms (80% of all leaves). The fungus was re-isolated from diseased leaves. These results suggest that *P. washingtonensis* is able to cause foliar blight on Pacific madrone when leaves are subjected to cold stress. Increased disease severity on madrone observed in spring 2011 in Washington and Oregon may have been due to predisposition of foliage to extreme cold in November 2010 and February 2011. This fungus has previously been reported to cause a postharvest fruit rot disease on apple fruit and a canker and twig dieback disease of apple and crabapple trees in WA (1). To our knowledge, this is the first report of *P. washingtonensis* causing a leaf blight disease on Pacific madrone in North America.

References: (1) C. L. Xiao et al. Mycologia 97:464, 2005. (2) T. J. White et al. Page 315 in: PCR Protocols: A Guide to Methods and Applications. Academic Press, San Diego, 1990.

Elliott, M., and R. L. Edmonds. 2008. Injected treatments for management of madrone canker. Arboriculture and Urban Forestry 34 (2): 110-115.

Abstract

Pacific madrone (*Arbutus menziesii*) has been experiencing a decline in the Puget Sound area, primarily as a result of a canker disease caused by the fungus *Fusicoccum arbuti*. Cultural methods such as prevention of stress and wounding are recommended to control canker diseases on trees. In addition to these, injected treatments can be used to protect valuable Pacific madrone trees in urban areas. An experiment testing injectable chemical fungicides and plant activators was performed on Pacific madrone trees inoculated with *F. arbuti.* There was little correlation between fungicidal activity in culture and canker reduction in the field tests. Two treatments that were effective in minimizing canker growth in inoculated madrones were Arbotect_ (Syngenta Crop Protection Inc., Greensboro, NC, U.S.; a triazole fungicide) and BioSerum™ (phosphorous acid). Cankers on wound inoculations were 50% smaller than the control group and no infections occurred on surface-inoculated treatments. Increased callusing was observed on cankers on trees with these treatments and the mode of action for these chemicals is probably stimulation of plant defenses rather than fungicidal action. Phosphorous acid is recommended in addition to cultural methods that improve tree vigor for high-value madrone trees in urban landscapes; however, heavily infected trees that have lost most of their crown will probably not benefit.

Key Words. Arbotect_; *Botryosphaeria*; canker; *Fusicoccum*; injectible fungicide; Pacific madrone (*Arbutus menziesii*); phosphorous acid; plant activator.

Farr, D. F., M. Elliott, and A. Y. Rossman. 2005. *Fusicoccum arbuti* sp. nov. causing cankers on Pacific madrone in western North America. Mycologia 97(3): 730-741.

Abstract
Pacific madrone (*Arbutus menziesii*) is a broadleaf evergreen tree native to western North America that has been in decline for the past 30 years. A fungus has been isolated and was verified as the cause of cankers on dying trees. It was determined to belong in the genus *Fusicoccum*, an asexual state of *Botryosphaeria*. This genus in both its sexual and asexual states commonly causes canker diseases of deciduous woody plants. Using morphological and molecular data the fungus causing cankers on Pacific madrone is characterized, described and illustrated as a new species of *Fusicoccum, F. arbuti* D.F. Farr & M. Elliott sp. nov. No sexual state is known for *F. arbuti*. Evidence from the literature, cultures and specimens suggests that *F. arbuti*, often mistakenly identified as *Nattrassia mangiferae*, has been causing madrone canker since at least 1968. Authentic isolates of *Nattrassia mangiferae* as the synanamorph *Scytalidium dimidiatum* were sequenced and determined to be different from *Fusicoccum arbuti* and to belong in *Botryosphaeria/Fusicoccum*. In addition to molecular sequence data, the morphology of the pycnidial and arthric conidial states of *Nattrassia mangiferae/ Scytalidium dimidiatum* resembles that of *Fusicoccum*. Therefore the correct name for *Nattrassia mangiferae* and its numerous synonyms (*Dothiorella mangiferae, Torula dimidata, Scytilidium dimidiatum, Fusicoccum eucalypti, Hendersonula toruloidea, H. cypria, Exosporina fawcetii, H. agathidia*, and *S. lignicola*) is *Fusicoccum dimidiatum* (Penz.) D.F. Farr, comb. nov.

Key words: *Arbutus, Botryosphaeria*, British Columbia, California, Canada, b-tubulin, forest pathology, *Fusicoccum, Hendersonula*, ITS, *Nattrassia*, Oregon, *Scytalidium*, systematics, Washington

Harrington, C.A. and Gould, P.J. 2015. Tradeoffs between chilling and forcing in satisfying dormancy requirements for Pacific Northwest tree species. Frontiers in Plant Science doi:10.3389/fpls.2015.00120

Abstract

Many temperate and boreal tree species have a chilling requirement, that is, they need to experience cold temperatures during fall and winter to burst bud normally in the spring. Results from trials with 11 Pacific Northwest tree species are consistent with the concept that plants can accumulate both chilling and forcing units simultaneously during the dormant season and they exhibit a tradeoff between amount of forcing and chilling. That is, the parallel model of chilling and forcing was effective in predicting budburst and well chilled plants require less forcing for bud burst than plants which have received less chilling. Genotypes differed in the shape of the possibility line which describes the quantitative tradeoff between chilling and forcing units. Plants which have an obligate chilling requirement (Douglas-fir, western hemlock, western larch, pines, and true firs) and received no or very low levels of chilling did not burst bud normally even with long photoperiods. Pacific madrone and western redcedar benefited from chilling in terms of requiring less forcing to promote bud burst but many plants burst bud normally without chilling. Equations predicting budburst were developed for each species in our trials for a portion of western North America under current climatic conditions and for 2080. Mean winter temperature was predicted to increase 3.2–5.5°C and this change resulted in earlier predicted budburst for Douglas-fir throughout much of our study area (up to 74 days earlier) but later budburst in some southern portions of its current range (up to 48 days later) as insufficient chilling is predicted to occur. Other species all had earlier predicted dates of budburst by 2080 than currently. Recent warming trends have resulted in earlier budburst for some woody plant species; however, the substantial winter warming predicted by some climate models will reduce future chilling in some locations such that budburst will not consistently occur earlier.

Lintz, H.E., Gray, A., Yost, A., Sniezko, R., Woodall, C., Reilly, M., Hutten, K., and Elliott, M.· 2016. Quantifying density-independent mortality of temperate tree species. Ecological Indicators 66:1-9.

Abstract

Forest resilience to climate change is a topic of national concern as our standing assets and future forests are important to our livelihood. Many tree species are predicted to decline or disappear while others may be able to adapt or migrate. Efforts to quantify and disseminate the current condition of forests are urgently needed to guide management and policy. Here, we develop a new indicator to summarize raw density-independent mortality of forested stands by species from the last decade of the 20th century to the first decade of the 21st century using forest inventory data. We define density-independent mortality to be stand mortality by species due to processes unrelated to natural mortality from succession or stand maturation, which is marked by overall increase in tree girth at the expense of density of individuals. We assess trends for 22 species on national forests in two U.S. states, Washington and Oregon. Populations of some species including timber species have no or low overall levels of density-independent mortality (*Juniperus occidentalis*, *Abies procera*, *Thuja plicata*, *Tsuga heterophylla*, *Pinus ponderosa*, and *Pseudotsuga menziesii*). In contrast, other species demonstrate unsustainable levels of density-independent mortality (*Pinus monticola*, *Arbutus menziesii*, *Pinus albicaulis*, *Abies lasiocarpa*, *Taxus brevifolia*, *Pinus contorta*, *Abies grandis*, *Picea englemanii*, and *Larix occidentalis*). Additionally, the net potential for unsustainable levels of density-independent mortality in standing populations does not necessarily warrant concern when examined across species for our study area and time period; however, when examined by species, the number of species in decline exceeds the number of species where mortality can be generally attributed to endogenous self-thinning. We argue that this work can aid management and policy decisions and our understanding of complex vegetation dynamics in a changing climate. Application of the indicator at larger spatial scales and in conjunction with data on migration and establishment may be used to address questions such as, how can we make cost-effective management decisions to ensure long-term sustainability of tree species and forests? Tree species distributions across the landscape are complex systems, and raw characterization of current trends occurring in forest inventories is important especially given the uncertainty associated with the modeling and prediction of complex systems such as tree species

McGregor, R.R., Sakalidis, M.L., and Hamelin, R. C. 2016. *Neofusicoccum arbuti*: a hidden threat to *Arbutus menziesii* characterized by widespread latent infections and a broad host range. Canadian Journal of Plant Pathology 38: 70-81. DOI:10.1080/07060661.2015.1135476

Abstract

The iconic tree species, *Arbutus menziesii* (Pacific madrona, madrone arbutus), has been in decline in the Pacific Northwest of North America for the past 40 years. It is thought that the fungal pathogen *Neofusicoccum arbuti* has contributed to the decline of this tree species. In recent years, there have been reports of declining arbutus in the coastal region of southern British Columbia, Canada. We conducted intensive sampling in a park with severely affected arbutus trees to determine the cause and prevalence of decline. The majority of arbutus trees sampled in this study had cankers associated with *N. arbuti* infection. We also sought to determine if *N. arbuti* has additional hosts that could act as a reservoir for this pathogen. Six new hosts of *N. arbuti* were identified, and a seventh was confirmed; these hosts spanned four taxonomic orders and included *Amelanchier alnifolia, Cytisus scoparius* (confirmed), *Gaultheria shallon, Ilex aquifolium, Rosa* sp., *Sorbus sitchensis* and *Spiraea douglasii*. Recovery of *Neofusicoccum arbuti* from both symptomatic and asymptomatic plant tissues of these hosts indicates that it potentially has a broad host range. It remains to be established if *N. arbuti* is also pathogenic to these hosts. These results highlight the importance of monitoring for this pathogen and assessing the extent of its geographic distribution and its ability to colonize various hosts.

Niemiec, S.S., G.R. Ahrens, S. Willits, and D.E. Hibbs. 1995. HARDWOODS OF THE PACIFIC NORTHWEST. Forest Research Laboratory, Oregon State University, Corvallis. Research Contribution 8. 115 p. http://ir.library.oregonstate.edu/xmlui/bitstream/handle/1957/7623/RC8.pdf?sequence=1

Pacific madrone chapter http://owic.oregonstate.edu/pacific-madrone-arbutus-menziesii

This publication brings together in one place information on the general characteristics, biology and management, harvesting and utilization, wood characteristics, and related literature of Pacific Northwest hardwoods. Species included are bigleaf maple, black cottonwood, California black oak, California-laurel, giant chinkapin, Oregon ash, Oregon white oak, Pacific madrone, red alder, and tanoak.