Appendix C
Madrona Management

The Pacific madrona (*Arbutus menziesii*) Pursh is a favorite tree of many Seattle residents. Urban populations of Pacific madrona in Seattle Parks have shown increasing signs of disease in the last thirty years. Fungal pathogens such as *Natrassia mangiferae* and *Phytopthora* species are major causes of decline in individual trees. Recent research indicates that a relationship exists between the decline of madrona trees, microclimate, site characteristics, and fungal pathogens. The results of research point to specific best management practices.

Specific recommendations for managing madrona trees are presented below. A review of current literature pertaining to management of Pacific madrona trees follows, with references.

- ***Soils surrounding the root zones of Pacific madrona trees should be managed to reduce the effects of soil compaction.*** This should include eliminating ongoing soil compaction and mitigating existing soil compaction. At least 4 inches of coarse woody mulch should be spread on top of Pacific madrone root zones to prevent further compaction. Care should be taken not to pile mulch against the stem of individual trees. If soils are already compacted an air spade can be used to loosen the soil before adding a layer of coarse woody mulch.

- ***Fertilizers should not be added to the root zones of Pacific madrona trees.*** Fertilizers can disrupt the mycorrhizal associations between beneficial fungi and roots of Pacific madrona trees. Disrupting this mycorrhizal relationship can reduce the supply of water and micronutrients to trees. Changing the balance of micronutrients may influence disease caused by foliar pathogens such as *Natrassia mangiferae*. Trees without healthy mycorrhizal associations will also become susceptible to fungal pathogens such as *Phytopthora* species. Elliott et al. (2000) found a significant decrease in mycorrhizal diversity of Pacific madrone roots as nitrogen in the soil increased.

- ***New Pacific madrona trees should only be introduced into sites with well-drained soil and full sun exposure.*** In nature, regeneration of Pacific madrona trees occurs after major disturbances such as fire or clearcutting, which results in full sun exposure. The ideal size for planting is in 1gallon pots, or smaller. Research has shown that the ideal size to transplant madrona trees in landscapes is as small as possible, since they survive best where they can establish roots first, then begin to develop above ground biomass.

- ***Fungicides should not be applied to the root zones of Pacific madrona trees.*** Fungicides can kill beneficial mycorrhizal fungi, which protect tree roots from pathogens.

<u>Natural distribution</u>

The Pacific madrona has a natural range that stretches form the east coast of Vancouver Island southward to San Diego, California. Madrones occur in areas that have experienced some disturbance due to logging, fires, or other activities that lead to open patches in the canopy (Kruckeberg 1996). They also occur in canyons (Whitney 1998), prairie edges, at the transition zone of water bodies, on upland slopes (Whitney 1998), cliff sides, on mountain slopes higher than 3,000 feet above sea level (Burns and Honkala 1990), and on bluffs or ridges often near salt water (Dirr 1998). Native soils occur in a wide range of textures, are often rocky and many are less than 1 meter deep. A common native soil characteristic is good drainage and low moisture retention in the summer (Burns and Honkala 1990). According to Adams et al. (1999) Pacific madrona will do best in well-aerated, well-drained sandy loam texture soils.

Rooting habit of Pacific madrona

Burns and Honkala (1990) found that two to five year old seedlings showed large variation in rooting pattern and length. Some seedlings had a curving primary root with moderate lateral development and others had moderately twisted primary roots that straightened out just below ground line and grew straight downward to a depth of twenty-three centimeters. Pelton (1962) found larger root systems present on seedlings in sunny sites, except when attacked by fungi. He also observed an absence of root hairs on seedlings and that damage to root tips stimulated branching.

Large uprooted trees suggest a root system composed of deep, spreading lateral roots (Burns and Honkala 1990). Zwieniecki and Newton (1995) examined the morphological adaptations of A. menziesii roots growing in rock fissures. They found roots in fissures as small as 100µm, as estimated by root thickness. Roots growing in narrow fissures developed flattened cortex tissue, and were ribbon like in shape. No normal root hairs were found on such flattened roots.

Mycorrhizal associations

Mycorrhizae are beneficial for roots of Pacific madrona trees. Roots of many plant species commonly form symbiotic associations with soil dwelling fungi. These root-fungi associations are called mycorrhiza (Trudell et al. 1999). Most of the dominant plants in boreal coniferous and temperate deciduous forest ecosystems form ectomycorrhizal associations, often with basidiomycetes (Read 1982). In many cases of mycorrhizal symbiosis the fungus involved enhances plant access to nutrients from the soil, increases rootlet size and longevity, translocates water to the plant and protects the rootlets from many pathogens (Killham 1994). There is evidence that ectomycorrhizal fungus can exert direct antibiotic effects upon pathogenic organisms. In all cases studied nutrients are transferred from the fungus to the plant roots across an interface. In most mycorrhizae organic carbon, fixed by photosynthesis, is transferred from the plant to the fungus. Mycorrhizae can immobilize toxic heavy metal such as zinc, cadmium, and manganese. They can improve soil structure by facilitating binding of soil aggregates (Coyne 1999).

Limited research on the optimal pH for growth of ectomycorrhizal fungi indicates that they grow best in the pH range of 3-5 (Smith and Read 1997). Mycorrhizal colonization is strongly influenced by concentrations of soil nutrients. High levels of soil nitrogen and phosphorous can inhibit the formation of mycorrhizal associations (Killham 1994). Increased inputs of sulfur and hydrogen ions as a wet deposition can have adverse effects on both partners in the mycorrhizal association (Smith and Read 1997). Fungicides applied to soils are toxic to mycorrhizal fungi. Other management practices such as tilling and burning vegetation can kill mycorrhizal spores in the soil. Mycorrhizae fungi are obligate aerobes so poor drainage and waterlogged soil limits mycorrhizal population size (Coyne 1999). Excessively low soil water levels also reduce mycorrhizal development possibly due to water stress on both the plant and fungal partner, or to changes in nutrient availability resulting from water stress (Killham 1994).

Roots of Pacific madrona trees form a type of mycorrhiza termed arbutoid. According to Trudell et al. (1999) arbutoid mycorrhizae form sheaths around root tips, of the host plant, and enters the cells of the roots forming thin coils. Smith and Read (1997) speculated that arbutoid mycorrhiza may serve the dual purpose of storage and to separate the plant from the soil. The Pacific madrona has been shown to form associations with basidiomycetes. Fungal associates of Pacific madrone can form ectomycorrhizae with other plant species (Smith and Read 1997). Trudell et al. (1999) found that A. menziesii trees growing near Douglas firs associate with a greater diversity of mycorrhizal fungi than trees not near Douglas firs and that they associate with many of the same mycorrhizal fungi.

Special adaptations

Tappeiner et al. (1986) report that Pacific madrone trees can sprout from burls, when their stems have been damaged. Burls are globe like structures of adventitious buds located below ground at the base of stems. They found that sprouted clump dimensions could be accurately predicted from parent stem diameter and time since cutting.

James (1984) described how perennial shrubs of the California chaparral, and plants found in other Mediterranean-type ecosystems, sprout after injury from an ontogenetically produced swollen stem base/root crown that she called a lignotuber. She differentiated burls from lignotubers in that the former often refers to woody tissue developed around stem wounds on trees and shrubs. Lignotubers are different in that they may serve as carbohydrate and nutrient sources and they are produced through gene expression and not as a result of injury. Lignotubers can produce stem or root sprouts from dormant, protected buds enabling repeated shoot production despite frequent fire damage. After injury of the plant canopy, the hormonal influence of apical dominance is removed and dormant buds develop into new stem or root tissues.

Vegetative regeneration is adaptive under conditions of stress such as fire and drought because it provides a mechanism for rapidly replacing foliage between fires and after droughts. Plants that are “sprouters” also tend to develop a deeper root system. The advantages conferred by a lignotuber are adaptive for plant species that have evolved to endure fire, such as A. menziesii (Edmonds et al. 2000).

Propagation

Pacific madrona fruits ripen in September and will remain on the tree until December. Seed-source berries can be collected from October to December. Berries should be dried or macerated to remove pulp from the seeds (Rose et al. 1998). Eight seeds can be obtained from each fruit (Gonzalez 1999). Dried berries or seeds can be stored at room temperature for one or two years (Roy 1974).

Hartman et al. (1997) advise cold stratification of seeds, at 2 to 4° C for two to three months after which the seeds can be started in flats. Seeds can also be stratified naturally outdoors over winter, in western Washington (Rose et al. 1998). Seeds can be germinated in flats with an equal mixture of peat and loam soil (Kruckeberg 1994), in a sand-peat medium (Rose et al. 1998) or in a fine seedling mix (Gonzalez 1999). Seedlings should then be placed in a warm, well-lit place. Seeds will begin to germinate in two weeks. After at least two or four true leaves appear the seedlings can be transplanted (Gonzalez 1999).

Seedling survival

Seedlings are difficult to transplant and should be planted in a permanent location when less than forty-five centimeters tall (Hartman et al. 1997). A. menziesii seedlings are slow growing (Burns and Honkala 1990), (Rose et al. 1998). Winters and Hummel (1999) transplanted seedlings from one-gallon and three-gallon pots into landscapes. After four years, they found that the plants were of similar size even though the three-gallon plants had been larger at the time of planting. In natural settings seedlings tend to become established on disturbed sites, on bare mineral soil or in semi-open forests (Burns and Honkala 1990). Shoffner (1999) found that light level had the greatest effect on seedling growth. Plants growing in full sun with weekly irrigation accumulated most biomass and maintained the highest rates of photosynthesis, despite moderate water stress.

Pests and Diseases

Many insects are known to attack Pacific madrona. A list of insect species known to feed on Arbutus menziesii is displayed in Table A-1. Environmental stresses that facilitate infection by fungi can reduce overall resistance of trees and allow insects to become established as well as disease (Trudell et al. 1999).

Pacific madrona trees are susceptible to attack by wide range of fungi. A list of fungal species that are known to cause disease in A. menziesii is displayed in Table A-2. Cracking due to sunscald or mechanically induced wounds can facilitate colonization by canker and decay fungi (Elliott 1999). According to Elliott (1999) environmental factors such as excess shade, regular watering and fertilization may predispose trees to successful attack by pathogenic organisms. Hunt (1999) suggests that root disturbance can stress A. menziesii trees and predispose them to attack by fungi such as *Phadcidiopycnis spp.*, which is not pathogenic to healthy trees. Trees that have grown up in shade often have a spindly growth form that may predispose them to canker diseases if adjacent shade trees are removed (Bressette and Hamilton 1999).

Scientific name	***Common name***	***Author***
(many)	aphids	(Dreistadt et al. 1994)
Aleuropleurocelus nigrans	black aleyrodid	(Johnson and Lyon 1991)
Chrysobothris mali	flathead borer	(Dreistadt et al. 1994)
Coccus hesperidum	brown soft scale	(Dreistadt et al. 1994)
Coptodisca arbutiella	madrone shield bearer	(Dreistadt et al. 1994)
Euphyllura arbuti	madrone psyllid	(Dreistadt et al. 1994)
Gelechia panella	blothch leaf miner	(Dreistadt et al. 1994)
Hemiberlesia rapax	greedy scale	(Dreistadt et al. 1994)
Hyphantria cunea	fall webworm	(Johnson and Lyon 1991)
Lithocolletis arbutisella	blotchminer	(Elliott 1999)
Malacosoma californicum pluviale	western tent caterpillar	(Johnson and Lyons1991)
Marmara arbutiella	leafminer	(Dreistadt et al. 1994)
Trialeurodes madroni	madrone whitefly	(Dreistadt et al. 1994)
Wahlgreniella nervata	manzanita aphid	(Johnson and Lyon 1991)

Table A-1 Insects known to attack the Pacific madrona

Scientific name	Common name	Author
Aleurodiscus diffisus	smooth patch	(Sinclair et al. 1987)
Armillaria spp.	white rot	(Elliott 1999)
Ascochyta hanseni	leaf spot	(Elliott 1999)
Botryosphaeria dothidea	(none)	(Sinclair et al. 1987)
Coccomyces quadratus	tar spot	(Elliott 1999)
Coniothyrium spp.	leaf spot	(Sinclair et al. 1987)
Cryptostictis arbuti	leaf spot	(Elliott 1999)
Didymosporium arbuticola	leaf spot	(Elliott 1999)
Diplodia maculata	leaf spot	(Elliott 1999)
Disaeta arbuti	leaf spot	(Elliott 1999)
Elsinoe mattirolianum	spot anthracnose	(Elliott 1999)
Exobasidium vacinii	leaf blister	(Byther 1999)
Formitopsis cajanderi	brown tip rot	(Elliott 1999)
Fusicoccum aesculi	asexual stage of B. dothidea	(Elliott 1999)
Heterobasidion annosum	Annosum root rot	(Sinclair et al. 1987)
Mycosphaerella arbuticola	leaf spot	(Pscheidt and Ocamb 2001)
Phellinus igniarius complex	white rot	(Sinclair et al. 1987)
Phyllosticta fimibriata	leaf spot	(Elliott 1999)
Phytophthora cactorum	root rot	(Sinclair et al. 1987)
Poria subacida	yellow root rot	(Elliott 1999)
Pucciniastrum sparsum	Rust	(Elliott 1999)
Pythium spp.	damping off	(Elliott 1999)
Rhytisma arbuti	tar spot	(Sinclair et al. 1987)

Table A-2 Fungal pathogens known to attack the Pacific madrona

References for Pacific Madrona Management

Adams, A. B. 1999. *Arbutus menziesii* and soils of the Puget Trough, Washington, pp 140-146. In Adams, A. B. and Hamilton, Clement W. (Eds.). The Decline of the Pacific Madrone. Pollard Group, Tacoma, Washington.

Burns, Russell M. and Honkala, Barbara H. 1990. Silvics of North America, Volume 2, Hardwoods. Forest Service, United States Department of Agriculture, Washington, D.C.

Coker, Philip R. 1999. Tree biology and proper arboricultural treatment of Pacific madrone, pp 109-117. In Adams A. B. and Hamilton, Clement W. (Eds.). The Decline of the Pacific Madrone. Pollard Group, Tacoma, Washington.

Coyne, Mark. 1999. Soil Microbiology: An Exploratory Approach. Delmar Publishers, Albany, New York.

Dirr, Michael A. 1998. Manual of Woody Landscape Plants: Their identification, ornamental characteristics, culture, propagation and uses: fifth edition. Stipes Publishing L.L.C, Champaign, Illinois.

Dreistadt, Steve H., Clark, Jack Kelly, Flint, Mary Louise. 1994. Pests of Landscape Trees and Shrubs. An Integrated Pest Management Guide. University of California, Oakland California.

Edmonds, Robert L., Agee, James K. and Gara Robert I. 2000. Forest Health and Protection. McGraw-Hill Higher Education, U.S.A.

Elliott, Marianne. 1999b. The Decline of Pacific Madrone (*Arbutus menziesii* Pursh) in Urban and Natural Environments: Its causes and management. University of Washington. Seattle, Washington.Elliot, M., Cline E., Trudell, S., Edmonds, R.L. 2000.

Influence of soil nitrogen and mycorrhizae on Pacific madrone decline. http://students.washington.edu/melliott/arbutus/apscps2000/

Gonzalez, Rico. 1999. Nursery production of Pacific madrone, pp 99-102. In Adams, A. B. and Hamilton, Clement W. (Eds.). The Decline of the Pacific Madrone. Pollard Group, Tacoma, Washington.

Hartman, Hudson T., Kester, Dale E., Davies, Fred T. Jr. and Geneve, Robert L. 1997. Plant Propagation: Principles and Practices: sixth edition. Prentice Hall, New Jersey.

James, Susanne. 1984. Lignotubers and burls – their structure, function and ecological significance in Mediterranean ecosystems. The Botanical Review. 50: 225-266.

Killham, Ken. 1994. Soil Ecology. Cambridge University Press, Cambridge.

Kruckeberg, Arthur R. 1996. Gardening with Native Plants of the Pacific Northwest. University of Washington Press, Seattle.

Johnson, Warren T. and Lyon, Howard H. 1991. Insects That Feed on Trees and Shrubs; second edition, revised. Comstock Publishing Associates, Ithaca, NY.Pelton, John. 1962. Factors influencing survival and growth of a seedling population of Arbutus menziesii in California. Madrono. 16 (8): 237-276.

Read, D.J. 1982. The biology of mycorrhiza in the Ericales. Canadian Journal of Botany. 61: 985-1004.

Rose, S.L., Perry, D.A., Pilz D. and Schoeneberger, M. M. 1983. Allelopathic effects of litter on the growth and colonization of mycorrhizal fungi. Chemical Ecology. 9 (8): 1153-1162.

Roy, Douglas F. 1974. ARBUTUS MENZIESII Pursh, pp 226-227. In . Schipmeyer, C.S., technical coordinator. Seeds of woody plants in the United States. Agricultural Handbook 450 U.S. Department of Agriculture, Forest Service. Washington D.C.

Pscheidt, Jay W., and Ocamb, Cynthia M. 2001. Pacific Northwest Plant Disease Management Handbook. Oregon State University.

Shoffner, Tony V. 1999. Light intensity, irrigation, and soil innoculation effects on establishment (of) *Arbutus menziesii* in urban landscapes, pp. 118-125. In Adams, A. B. and Hamilton, Clement W. (Eds.). The Decline of the Pacific Madrone. Pollard Group, Tacoma, Washington.

Sinclair, Wayne A., Lyon, Howard H. and Johnson, Warren T. 1987. Diseases of Trees and Shrubs. Comstock Publishing Associates, Ithaca and London. Smith, Sally E. and Read, David J. 1997. Mycorrhizal Symbiosis: second edition. Academic Press, San Diego.

Trudell, Stephen A., Cline, Erica T., Elliott, Marianne., Edmonds, Robert. 1999. Possible role of mycorrhizas in resistance to decline in *Arbutus menziesii*, pp. 130-135. . In Adams, A. B. and Hamilton, Clement W. (Eds.). The Decline of the Pacific Madrone. Pollard Group, Tacoma, Washington.

Whitney, Stephen. 1998. Western Forests. Alfred A. Knopf, Inc. New York.

Zwieniecki, Maciej. and Newton, Michael. 1995. Roots growing in rock fissures: Their morphological adaptation. Plant and Soil. 172: 181-187.