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Determining Causes of Pacific Madrone Decline in Urban Landscapes of the Pacific Northwest

Dana Kelley Bressette and Clement W. Hamilton

Abstract: In order to determine factors contributing to the decline of the Pacific madrone (*Arbutus menziesii*), 103 trees were surveyed and rated on a scale of 1–4. The performance rating was then compared with the following plant parameters and site conditions: size, growth habit, bark characteristics, location and size of cankers on the trunk, light exposure, slope, soil characteristics, management practices and competing vegetation. Significant correlation was found between performance and: 1) growth habit—spindly trees did poorly compared to bushy trees; 2) percent cankering on the trunk; 3) persistent bark—trees that experienced peeling bark on their trunks looked poorer than those that retained a thick layer; 4) soil texture—trees growing in silty or clay loam soils performed poorly; and, 5) sprouting at root collar—trees experiencing dieback often produced sprouts near the base of the trunk (results of the completed research, involving 300 trees, are summarized at the end of the paper). The most serious tree decline occurs where urban development exposes trees previously growing in the forest. Trees growing in a forest are tall and spindly compared to trees growing in the open. Thick bark retained under shady conditions is shed when exposed to strong sunlight. Both of these factors may make madrones more susceptible to canker diseases. Knowledge of how a madrone can be expected to perform in a landscape is of value to landscapers desiring to incorporate or plant madrones into a landscape and to landscape managers caring for madrones in existing landscapes.

Many persons have noticed that in areas around the Puget Sound the Pacific madrone (*Arbutus menziesii*) appears to be declining. Many trees can be seen with dead or dying twigs and branches. This has caused concern for the health of the species throughout our area. In fact, at least 3 canker diseases may infect madrone in this area: *Arbutus* canker [*Nattrassia mangiferae* (formerly *Hendersonula toruloidea*; Davison 1972 and Hunt, *et al.* 1992)], *Phytophthora* root rot (*Phytophthora cactorum*) (Stuntz and Seliskar 1943) and madrone canker [*Fusicoccum aesculi* (Burns and Honkala 1990; *cf.* Elliott this volume]. Canker diseases have a major impact on many trees in certain situations; there are, however, also many healthy, young trees so that, in reference to the species as a whole, we could borrow a quote from Mark Twain, that "...the reports of [its] death are greatly exaggerated."

Large madrones found in many old parks and landscapes around the Puget Sound are highly valued for their aesthetic appeal (Kelley, *et al.* 1993). The decline of many of these old trees has sparked an interest by many citizens in determining whether it is possible to slow or halt the decline of these beautiful trees.

In order to determine whether it is possible to slow the decline of mature trees and whether planting young trees is worthwhile, we must answer several key questions, which fall under 4 categories. 1) Under what conditions does madrone perform well? and, conversely, under what conditions is madrone susceptible to canker diseases? Are there factors that create stressful conditions causing the madrone's increased susceptibility to these diseases? 2) How should a tree be managed in the landscape in order to maintain good health, and do existing management techniques actually contribute to the infection and the subsequent decline of madrones? 3) Can dying trees be successfully replaced with young trees, or are they likely to succumb to the same diseases? 4) Can we predict the success of newly planted madrones with some knowledge of site conditions? In this paper we present preliminary findings that begin to answer these critical questions.

Literature about Pacific madrone is scattered in many journals. Most of the important papers are referred to in this volume. Four additional references that deserve mention are Pelton (1962), Bullen and Wood (1979), Molina and Trappe (1982) and Acsai and Largent (1983).

METHODS

The goal of this research is to survey 300 mature trees in the Puget Sound Region. Most trees surveyed are from urban sites: parks, commercial sites, residential neighborhoods and roadsides. Some rural and more natural sites are also included in the final report (Bressette 1995). At each site we assess the growing conditions, plant parameters and the performance of the plant, which we then analyze for correlations that would answer the questions posed above.

The trees are rated for performance on a scale of 1–4, according to the amount of dieback in the canopy of the tree: 0–25% dieback rated 4 (good), 26–50% rated 3, 51–75% rated 2, 76–100% rated 1 (poor). The performance rating is then compared with several plant parameters and site conditions. The plant parameters are:

1) Size—diameter at breast height (DBH) and approximate height are measured because they may be an indirect measure of relative age. Age may affect the relative health of trees due to a decline of vigor as a tree ages. Very young trees are not included for this reason. Although some diseased young trees are seen, most young trees appear healthy and vigorous.
2) Growth habit—the form of a tree suggests early growing conditions. A tree that originally was growing in a forest usually has one tall, slender trunk with foliage only near the top in order to capture light; whereas a madrone growing in an open, exposed site is more shrub-like, often with many stems.
3) Bark characteristics—one of the most attractive attributes of the madrone is its red, peeling bark. The bark usually peels only where it is exposed to strong light (Coe 1983). Canker diseases such as Hendersonula dieback occur more readily in trees with thin bark (Sinclair, *et al.* 1987).
4) Location and size of cankers on trunks—presence of cankers on the trunk should be reflected in the health of the canopy, depending on the percent of the trunk girdled by the cankers.
5) Light exposure—the amount of sunlight the tree receives affects growth and vigor. Tree trunks or branches exposed to sunlight are susceptible to sunscald in the winter (Harris 1992).
6) Slope—poor water penetration into soil due to steep slopes may affect growth.
7) Soil characteristics—horticulturists often are concerned with the impact of urban activity on soil. Compaction is common and it decreases air and water movement in the soil. Mulching trees and shrubs, as well as adding organic matter, is thought to decrease these effects. Soil texture affects the movement of water in the soil. Nutrient availability is affected by pH. The presence and availability of nutrients in the soil is critical for plant health.

8) Management practices—the way madrones are managed in a landscape influences the health of the trees. Irrigation has often been blamed for the decline of madrones (MacDonald 1989 and Grant and Grant 1990). Fertilization and pesticide use may have either positive or negative effects. Pruning practices are very important because pruning cuts provide entrance wounds for pathogens.

9) Competing vegetation—knowing how well madrones grow in competition with other plants and which plants may serve as good "companion" plants helps select plants for surrounding landscapes.

PRELIMINARY RESULTS

At the time of the symposium one third (n = 103) of the intended sample size of 300 was surveyed. A preliminary statistical analysis was performed using Chi-square contingency table analysis. Each parameter was compared with the dieback rating.

Table 9-1 shows an example of how each parameter, in this case growth habit, is compared to the dieback rating. The contingency table shows the number of observations in each category. In this example there were many more bushy trees (15) with the "4" rating than would be expected (5.25) and many more tall, spindly trees (14 actual versus 7.56 expected) with a "1" rating.

Table 9-1. Example of contingency table for parameter growth habit: actual number of observations (O) versus expected frequencies (E). Expected frequencies at each position in the table are determined by dividing the product of the row total (R) and column total (C) by the total number of observations (n): [(R*C)/n]. The probability of independence is calculated using the chi-square statistic(the p-value< 0.0001): the sum of the observed minus expected value squared divided by the expected value: $\Sigma(O_{ij}-E_{ij})^2 / (E_{ij})$ where i and j designate the column and row, respectively.

Growth habit	Dieback rating 1		2		3		4		Row totals
	O	E	O	E	O	E	O	E	
Bushy	2	5.7	1	4.4	3	5.7	15	5.3	21
Intermediate	11	13.8	12	10.7	19	13.8	9	12.8	51
Tall	14	7.6	8	5.9	5	7.6	1	7	28
Column Totals	27		21		27		25		100

Table 9-2. P-values of site parameters compared to dieback ratings (alpha = 0.1, * denotes significance).

Parameter	p-value
Growth habit	<0.001*
percent cankering on trunk	0.004*
Persistent bark	0.033*
Soil texture	0.067*
Sprouting at root collar	0.088*
Permeability	0.167
Road or trail within 3 m.	0.231
Level of management	0.234
Pruning	0.251
Surface leaves	0.331
Vegetation	0.365
Bulk Density	0.376
Height	0.422
Soil depth	0.529
Exposure	0.593
Soil surface	0.761
DBH	0.757
Organic Matter	0.817
Slope	0.900

Results are “significant” when there are large differences in actual versus expected frequencies. We calculate the probability (p-value) that the pattern we find is due solely to chance. In this example, the probability is very low that this pattern could occur randomly, which suggests that the correlation between bushiness and good performance is real.

Table 9-2 shows the p-values calculated for different parameters. The lower the p-value, the higher the correlation between the parameter and canopy dieback. A p-value of 0.10 or below was chosen to suggest significance. In other words, we considered a correlation significant when the random probability of the resulting pattern is less than 10% (correlation does not necessarily reflect causation).

In this preliminary analysis the following parameters are significant: 1) Growth habit—bushy trees perform much better than tall, spindly trees. Although an attempt was made to look at actual dead branches, not just the overall shape of the canopy, there may be some bias in the determination of the performance rating in relation to this category. Tall, spindly madrones acclimated to growing in a forest are severely impacted when exposed due to urban development. 2) Cankering—percent cankering on the trunk is highly correlated with dieback in the canopy. This is expected due to disruption of the vascular system. 3) Persistent bark—the location and presence of persistent bark affects the tree's susceptibility to canker diseases. There is more dieback in trees where the bark peeled on the south side of the tree and less where there is thick bark surrounding the tree. Thin bark is much more susceptible to damage and subsequent invasion by pathogens (Davison 1972 and Sinclair, *et al.* 1987). 4) Soil texture—there is more dieback in trees growing in silty or clay loam soils. This is probably related to moisture problems. Madrones are more commonly found in rocky soils with good drainage and low moisture retention in the summer (Burns and Honkala 1990). Madrones are known for their ability to withstand dry periods (Morrow and Mooney 1974) but may become stressed in poorly drained soils. 5) Sprouting—this is most likely a response to rapid top dieback when the roots are still relatively healthy. Madrones readily produce stump sprouts. Clumps of stump sprouts can grow quickly so that madrones can dominate stands, outcompeting conifers, for many years after clear-cutting (Burns and Honkala 1990).

Other parameters with low p-values may affect dieback of madrones although they are not statistically significant in this analysis. These parameters are: 1) permeability—there is more dieback in trees growing in soil with low permeability; 2) road or trail within 3 m—although this parameter has a fairly low p-value, there is no clear pattern in the presence of a road or trail to dieback in the canopy; 3) level of management—many trees in areas of high management, such as in turf areas, experience more dieback; 4) Exposure—trees are affected where the trunk is exposed and by partitioning the data, to exclude "bushy" trees, a more significant result may be found; and, 5) soil analyses—statistical analyses are not complete, so nothing is yet known about what effect differences in pH and soil fertility have on dieback. None of the remaining parameters show any discernable correlations.

DISCUSSION

It was observed that madrones grow very differently in response to light. When found growing in a forest, madrones grow tall and spindly in an effort to compete for light at the top of the canopy. They are also often seen leaning over roads or over bluffs of the Puget Sound at a forest's edge reaching towards the light. The vascular system of some trees often appears to spiral around the trunk, indicating that the young tree twists like a vine as it grows seeking the light. When growing in the open, madrones tend to grow shorter and more shrub-like.

It was also observed that trees growing in the shade tend to retain a thick bark on their trunks, whereas bark exposed to more light is shed to reveal a smooth greenish bark layer that later turns orange-red (Coe 1983). This phenomenon is easily seen where tree trunks are exposed to sunlight. The north side of the trunk often retains its thick bark whereas the bark on the south side peels. On leaning trees, the top sides of the trunks also usually exhibit peeling bark. Peeling occurs in the hottest part of the summer and may be due to a drying and shrinking of the bark (Hunt this volume). This phenomenon seems more prevalent in trees and shrubs native to warm climates. The adaptive purpose of this phenomenon is unclear. Peeling bark may reduce the heat load on the trunk of the tree, but it is also possible that this phenomenon has no adaptive function.

These 2 factors, spindly growth and shedding bark, plus urban development appear to make madrones susceptible to canker diseases. One probable sequence of events that leads to the decline of a madrone is as follows.

1) When urban development occurs, surrounding trees are taken down, exposing the trunks of tall, spindly madrones left behind.
2) In response to stronger sunlight, the thick bark is shed.
3) The resulting thin bark is more susceptible to damage by sunscald or other factors.
4) Damaged bark predisposes the tree to infection by pathogens. Davison (1972) showed that, although *Nattrassia* (*Hendersonula*) can infect an unwounded tree at the ideal temperature of 25^{o}C, a higher incidence of disease results from wounding.
5) The pathogen causes a perennial canker.
6) Thereafter, a "tug-of-war" ensues between the pathogen and the tree; the pathogen increases the size of the canker during seasons that it is more active, and the tree responds by attempting to grow tissue back over the canker when the pathogen is less active.
7) The madrone begins to lose when it weakens as more of its vascular system is destroyed. The tree is eventually girdled.

Many other scenarios are possible as well. Any stress, such as poor drainage, may weaken the tree and decrease its ability to withstand infection. Leaf loss due to poor water relations may cause exposed twigs to be more susceptible to damage by freezing, as well as ease the ability of fungal spores to come in contact with twigs.

Unfortunately, the prognosis is not good for existing Pacific madrones that originally were growing in a forest and are now isolated and exposed. They will probably succumb to canker diseases in the following decades. Tall, spindly trees, if cut down early after development (before they begin to decline, may stump sprout and quickly revegetate the landscape. Allowing regeneration by stump sprouting or natural seed germination as well as replanting with young, nursery-grown trees may be viable options where site conditions are favorable for growth and disease inoculum level is not too severe (Byther this volume). Those trees severely infected should be removed to reduce the inoculum level.

Other trees have a much better chance as long as they remain in vigorous, good health and retain a full canopy. Maintaining good horticultural practices is recommended to encourage healthy trees.

Pruning in general is not advised until we know more about the effects of types and timing of pruning on the madrone. The removal of limbs increases the exposure of trunks and branches. The wounds caused by pruning often provide entrance to fungal pathogens.

It is unfortunate that 2 of the features considered most attractive in madrone — the thin, reddish bark and dramatic arborescent form — are characteristics that may make it vulnerable to attack by pathogens. The madrone's value as an ornamental species is dependent upon its ability to withstand or tolerate canker diseases. Landscapers may be more willing to incorporate or plant madrone into urban landscapes with knowledge of its growth habit, management requirements and probability of successful establishment. Whether in urban landscapes or in the wild the madrone continues to be valued as an attractive native tree species of the Pacific Northwest.

RECENT RESULTS AND DISCUSSION

Since this paper's presentation at the symposium, Bressette (1995) has completed the analysis whose preliminary results were presented at the symposium. Plant parameters reported above as having high correlation with plant performance and whose correlation remained strong after analyzing all 300 trees included growth habit, trunk cankering and peeling bark. Soil texture and sprouting at root collar reduced in significance. In the final analysis 4 other plant parameters were found to correlate well with plant performance. Trees growing adjacent to a road or trail actually performed better than expected, as did trees with more leaves remaining on the soil's surface. Trees did best growing with native vegetation or with no vegetative competition at all. Finally, shorter trees performed better than taller ones.

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