PART IV

MADRONE IN

HABITAT

RESTORATION

14

Light Availability, Irrigation and Native Soil Effects on Establishment of *Arbutus menziesii* in Urban Landscapes

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Abstract: Pacific madrone (*Arbutus menziesii*) is in decline in urban areas of the Pacific Northwest. Maintaining significant populations of this species requires development of restoration techniques for urban environments. My research consists of investigating the effects of light, irrigation and native soil on the establishment of Pacific madrone. I transplanted 104 one year madrone seedlings into an urban site that has sufficient variation in light environments to provide full and partial sun exposure treatments. Nested treatments of native soil addition and irrigation are imposed within the separate light treatments. During the experimental period, I measured for overall plant growth and biomass accumulation, carbon dioxide (CO_2) uptake and water stress levels. Experimental results are useful in habitat restoration and revegetation applications for Pacific madrone.

INTRODUCTION

As a signature species of Pacific Northwest coastal areas, Pacific madrone (*Arbutus menziesii*) has intrinsic and horticultural value. It is appreciated as a native plant. Presently the population of madrones in urban areas is dwindling, and the decline of mature madrones is attributed to various diseases. As with other plants in urban areas, madrones are susceptible to high levels of various stresses which create predisposing conditions (*e.g.*, sunscald injury, freeze damage, drought and saturated soils) for infection (Davison 1972 and Sinclair, *et al*. 1987). Natural regeneration of madrone is difficult in urban areas, thus, here is where the threat of decline is most imminent.

Survival and growth of madrone seedling populations is inhibited, with a majority of the population dying within the first year (Pelton 1962 and Tappeiner, *et al*. 1986). Much of the mortality is attributed to external factors such as damping-off, predation, drought and litterfall. First year biomass accumulation of Texas madrone (*Arbutus xalapensis*) is lower in seedlings exposed to high light levels and low water availability than those without these stresses (Whitenberg and Hardesty 1978). Although these studies focused on seedling populations in natural environments, urban conditions also present many stresses which decrease the percentage of seedling establishment and decrease growth and development. If in urban areas the rate of regeneration is very low, while at the same time mature tree decline due to disease accelerates, the numbers of madrones decrease.

My project investigates growing madrone seedlings under controlled conditions for one year. Planting saplings could possibly bypass stresses known to reduce the percentage of germination and establishment among naturally occurring seedlings. Madrone seedlings produced under controlled conditions achieve greater heights and accumulate more biomass in the first year than those occurring naturally (Pelton 1962 and Tappeiner, *et al*. 1986). This lessens the likelihood of mortality before establishment. Successful transplantation and establishment of madrone seedlings is extremely difficult (McDonald and Tappeiner 1990). For successful establishment, we must first know which environmental factors most affect establishment.

In this study light intensity, water availability and native soil addition are observed as factors that affect establishment and growth. Madrones grow in both very low light and with full sun exposure and are also considered drought tolerant. Native soil from beneath mature madrones is added to provide mycorrhizal inoculum. Mycorrhizal associations benefit many plants [particularly Douglas-fir (*Pseudotsuga menziesii*)] during establishment (Perry, *et al*. 1989). Madrone also have mycorrhizal associations (Zak 1974 and Acsai and Largent 1983). Whether or not, or how, these factors influence madrone during establishment is still unknown. Site factors (*e.g.*, soil characteristics and percent canopy cover) are measured to better understand conditions imposed upon seedlings.

My project is designed to study how nursery-grown Pacific madrone seedlings establish when planted into urban landscapes, and the effect of the aforementioned environmental factors upon growth and establishment. Specifically, my objectives are: 1) to establish base line data on growth characteristics of Pacific madrone seedlings; 2) to evaluate overall plant performance based upon the site characteristics and controlled treatments imposed upon the plants; 3) to measure how light availability, regular irrigation and adding native soil affect the establishment of Pacific madrone seedlings; 4) to define environmental factors (aspect, canopy cover, soil characteristics and precipitation levels) that may influence plant growth; and, 5) to develop guidelines for successfully using madrone in restoration and revegetation projects.

METHODS

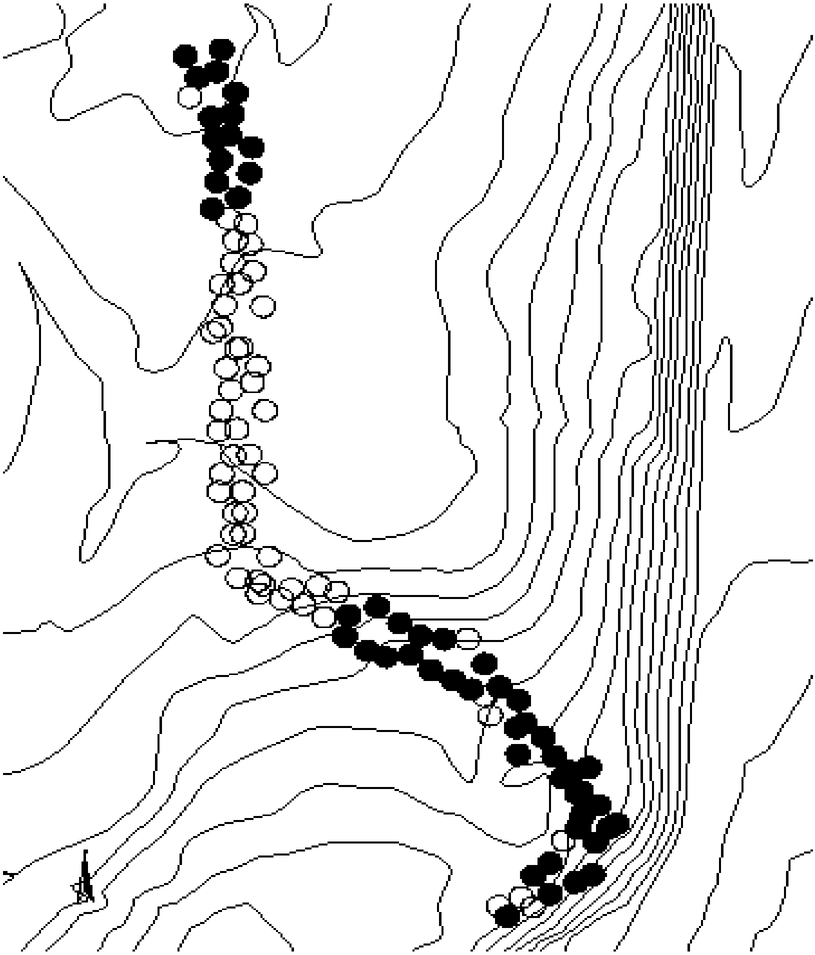
I used 168 year-old Pacific madrone seedlings that range from 6–47 cm (2–17 in) in height. Plants were grown using standard nursery practices (Gonzalez this volume) at the Center for Urban Horticulture, University of Washington, Seattle. I collected seed from a single mature Pacific madrone at Washington Park Arboretum in an effort to minimize effects due to genetic variation or provenance.

At Discovery Park in Seattle, a 250 m roughly north to south transect was drawn (Figure 14-1). The northern most 30 m of the transect is under deep shade. Continuing south, the transect crosses an open meadow for 125 m. At 155 m, the transect angles to the southeast for the remainder of its length, ending in a shaded, mixed conifer — hardwood stand.

I planted the saplings on March 15, 1995 with the following design. I randomly placed 104 seedlings along the transect. Beginning at one end of the transect, and continuing every 5 m after, plants were planted from 0 to 5 m (16.4 ft) away from the transect line, on both sides (2 plants every 5 m along the transect). I determined distances away from the transect by selecting numbers from a random number chart. Wherever a tree, path or other obstruction occurred at a randomly chosen point, the planting site was moved a meter farther until a sufficient planting site was found. After planting I drove 3 stakes into the ground around each plant, and a piece of yellow nylon rope was connected between the stakes to create a fence.

The plants were divided into 8 treatments (combinations of full or partial sun exposure, regular or no irrigation and native soil addition or no addition). The full sun and partial sun treatments included 52 plants each. Nested treatments of irrigation and no irrigation and both levels of native soil addition were imposed on full sun or partial sun treatments to create 4 groups of 13 plants within each light treatment. At planting, soil from the rhizosphere of a mature madrone was added to holes for plants in the native soil addition treatment. Fifteen cm (6 in) of mulch was applied over the planting ring, and all plants were irrigated (Whitcomb 1979). Irrigation treatment plants received 4 liters of tap water weekly unless 2.5 cm of precipitation fell. Rainfall was measured weekly from a rain gauge located on site.

Prior to planting, I measured height, leaf number, stem number and total stem length (total length of all stems including the main leader) for all plants. I noted any significant observations, such as leaf coloration, insect damage and phenology. To gather base line data, I randomly



1:1200 1 cm = 12 m 1 inch = 100 feet

Figure 14-1. Pacific Madrone (*Arbutus menziesii*) seedling growth and establishment research project. Sun treatments. solid circle = partial sun (< 54% sky), open circle = full sun (³ 54% sky). Study site is ~ 50 m from the south parking lot in Discovery Park, Seattle, Washington.

selected 10 remaining plants for destructive harvests, and the same measurements taken. The leaves, stems and roots were dried for 24 hours at 100°C, after which I weighed the dry biomass (Table 14-1). Harvests for the same measurements were taken in November following the growing season using randomly selected plants from all combinations of treatments.

Beginning at bud break, the plants were measured weekly for height, stem number and total stem length to measure growth rate. Beginning in June and ending in October, photosynthetic rate and stomatal conductance measurements were taken once a month using a LI-COR 6250 Infrared Gas Analyzer (Pearcy, *et al*. 1989 a, b and c). Measurements were taken on days with maximum sunlight (between 11:00 and 13:00 PMT), and measurements used to determine overall plant performance. Photosynthetic capacities of plants are affected by various levels of light intensity and water availability. For most plants, 90% of maximum net photosynthesis occurs between 1/3 and 2/3's

Table 14-1. Baseline harvest data. (A) Height, stem and root data. (B) Leaf and whole plant data. Data for March, 1995.

A

Plant	Height (cm)	Stem number	Stem length (cm)	Stem dry weight (g)	Roots dry weight (g)
145	17.0	1	17.0	2.8	8.2
146	26.0	1	26.0	3.2	6.0
147	31.0	2	46.0	8.5	13.0
148	30.5	1	30.5	3.9	10.4
149	10.5	1	10.5	0.8	4.1
150	36.0	1	36.0	6.6	13.0
151	37.5	1	37.5	8.3	18.0
152	27.5	5	68.0	7.8	12.5
153	23.5	1	23.5	3.3	11.7
154	12.5	1	12.5	0.8	2.8
Mean	**25.2**	**1.5**	**30.8**	**4.6**	**10.0**

B

Plant	Leaf number	Leaf area (cm3)	Leaf dry weight (g)	Whole plant dry weight (g)
145	23	560.2	12.9	23.8
146	21	544.8	12.5	21.7
147	32	872.1	18.9	40.3
148	28	813.9	16.3	30.6
149	19	279.0	6.0	10.8
150	22	894.9	20.5	40.0
151	29	1110.7	27.1	53.4
152	54	1057.6	22.7	43.0
153	22	714.7	14.4	29.3
154	19	289.6	6.1	9.8
Mean	**26.9**	**713.6**	**15.7**	**30.3**

of full sunlight (Kazlowski, *et al*. 1991). For each set of measurements, 20 plants (5 from each combination of light and irrigation treatments) were measured. By the end of the study period, 100 plants were analyzed for photosynthetic rate and stomatal conductance.

On dawn of the day after the photosynthesis measurements, I took water potential measurements (psi_{pd}) of a healthy, mature leaf from the uppermost portion of each plant using a Scholander Pressure Bomb (Scholander, *et al*. 1965 and Ritchie and Hinckley 1975). I used these measurements to determine stress levels between plants of separate treatment combinations. Water is one of the most limiting factors for plant growth (Kozlowski, *et al*. 1991). Although mature madrones withstand severe levels of water stress, maintaining adequate water status is crucial to survival for most plants during establishment (Morrow and Mooney 1974 and Beeson and Gilman 1992).

I took site characterization measurements to determine the environmental factors (*e.g*., available light and soil conditions) and percent available light (canopy cover) measurements were taken once at each plant location using a hemispherical lens attached to a 35 mm camera (Pearcy, *et al*. 1989a). I used an image analysis method to determine canopy architecture and percent of available light (Rich 1990).

Eleven soil samples (one sample every 25 m along the transect) were analyzed (pH, texture and percent carbon, hydrogen and nitrogen) to identify differences within the soil between locations along the transect. A common soil characteristic of locations where madrones occur is good internal drainage and low moisture retention in the summer (McDonald and Tappeiner 1990). Preliminary examination indicates that soil at the site is very sandy and well drained. I tested for differences in success of plant establishment, growth and plant performance in relation to site factors and treatments with statistical analysis.

DISCUSSION AND CONCLUSIONS

Data gathered during the study period, including field and destructive harvest measurements, quantitatively define Pacific madrone's ability to establish and grow under various conditions within the urban environment. By measuring growth rates, overall biomass accumulation and individual plant performance in the field, I gained an understanding of the conditions which are most beneficial or inhibiting for establishment and growth of container-grown madrone seedlings.

My research helps to answer questions regarding the importance of irrigation for establishment and growth of Pacific madrone seedlings, the ability of madrones to establish in a wide range of light environments, and the potential benefits derived from mycorrhizal inoculation. Ultimately, my research should prove useful for future restoration and revegetation projects involving the Pacific madrone. I hope that it provides guidance for more research aimed at studying Pacific madrone's ability to establish, grow and develop in urban environments.

RECENT RESULTS AND DISCUSSION

Since this paper's presentation, I have completed analysis of the design and preliminary results presented above (Shoffner 1996 and Shoffner and Gonzalez 1998). I found that different treatments have no significant effects on survival, possibly due to heavy precipitation during the normally arid summer. Growth, however, differs significantly among the treatments—plants growing in full sun with weekly irrigation accumulate the most biomass and maintain the highest rates of photosynthesis despite moderate water stress. Light level has the greatest effect on seedling growth, with secondary effects by irrigation and addition of native soil.

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