Comparison of Mist, Fog, and Electrostatic Fog for Vegetative Propagation of Difficult-to-Root Plants®

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There is an expanding market for nursery-produced native California plants, but their production is limited because many are difficult to propagate from cuttings. We are studying two barriers to successful propagation: low competence of stem cuttings from source plants and deterioration of cuttings due to environmental conditions during rooting. The primary objectives of the project are to test methods for improving the competence of difficult-to-root species by the manipulation of stock plants, and to test novel fog chambers to enhance the rooting environment. We used three types of bottom-heated propagation benches: standard mist benches and fan-and-pad-cooled fog chambers with either standard or electrostatic fog nozzles. Leafy cuttings of *Carpenteria californica, Dendromecon rigida, Garrya elliptica* 'Evie' and *G. elliptica* 'James Roof', *Rhamnus californica* 'Eve Case'*, Ribes speciosum,* and *Romneya coulteri* were taken from container-grown stock plants maintained in either a greenhouse or a lath house or from plants in the University of California Davis Arboretum. We found no consistent effect of either propagation bench type or concentration of IBA on rooting percentage. Higher rooting percentages were obtained from greenhouse-grown plants and plants growing outdoors yielded the lowest rooting percentages. The highest rooting percentages for most species (from 48% for *G. elliptica* 'Evie' to 80% for *C. californica*) were obtained from cuttings taken in January from plants grown under HID lamps in a greenhouse. However, it is not clear whether the lower rooting percentages in other seasons were due to cutting source material or inadequate environmental control in the propagation chambers. Rooting percentages for *Rhamnus* cuttings were consistently high, averaging 81% across all experimental conditions. Average rooting percentages in fog chambers over time for the other species were 44% for *Carpenteria*, 5% for *Dendromecon*, 38% for *G. elliptica* 'Evie', 32% for *G. elliptica* 'James Roof', and 23% for *Romneya*. Propagation of *Ribes* in the fog chambers was unsuccessful.

INTRODUCTION

Nursery-grown California native plants are in demand, but their production is limited, mainly because many are difficult to propagate. Vegetative propagation is commonly preferred over sexual propagation because it allows the grower to maintain desirable traits and have more uniform plants, but it can be difficult to keep cuttings alive long enough to allow for adventitious root formation.

During propagation of leafy cuttings one must minimize transpiration demand, maintain a suitable temperature to stimulate metabolism in the base of the cutting, and maintain irradiance within a range sufficient to generate photosynthetic production of carbohydrates for root growth (Loach, 1988). Two systems to achieve this environment are mist benches and fog chambers. The mist system minimizes water loss from leaves by decreasing their temperature, whereas fog will do it mainly by increasing humidity of the air and decreasing the vapor pressure deficit. The advantages of fog over mist are that nutrient leaching from the foliage and over-wetting of the medium are avoided, and also, because less water evaporates from the surface of the rooting medium, the medium is not cooled to the same extent, so less basal heating is required to maintain a favorable base temperature (Loach, 1988; MacDonald, 1986).

The main purposes of this research were to develop procedures for stockplant maintenance that enhance cutting rootability, determine the optimal environments for rooting of leafy cuttings of some California natives, and to compare rooting on mist benches with that in fog chambers equipped with standard or electrostatic fog nozzles.

MATERIALS AND METHODS

Carpenteria californica, *Dendromecon rigida*, *Garrya elliptica* 'Evie', *G. elliptica* 'James Roof', *Rhamnus californica* 'Eve Case', *Romneya coulteri*, and *Ribes speciosum* plants in 1-gal containers were purchased in Summer 2003 and placed in a greenhouse (22 °/18 °C day/night air temperature), then transferred to tall 3-gal containers (39 × 20.5 cm) in Fall 2003. During winter, metal halide lamps provided supplemental light between 8:00 AM and 10:00 PM. The plants were irrigated as needed with a modified half-strength Hoagland's solution.

In late Feb. 2004, half of the plants of each species were moved from the greenhouse to a lath-house. Those plants were also irrigated with a half-strength Hoagland's solution, but did not receive supplemental light.

The mist propagation bench was 3.7 × 1.5 m, with a heated sand bed covered with permeable woven plastic groundcloth. Mist is provided from overhead nozzles on 1.5-m centers, controlled by an electronic leaf. Benches had 0.75-m-high plastic side and end walls. The four fog propagation chambers were 3.7 m long, 1 m wide, 1.4 m tall at the ridge, and 1 m tall at the sidewalls. The chamber walls and roof were covered with polyethylene film. One end was fitted with an evaporative cooling pad, the other with a variable speed exhaust fan. The base of the chambers was insulated from the bench below and heated with electrical resistance mats. Two chambers were fitted with standard air-water fog nozzles (Spraying Systems Inc.). Compressed air was introduced at a pressure of 140 kPa. Water was introduced through a Venturi port in the nozzle at a rate of about 28 $ml \cdot min^{-1}$. Two other chambers were fitted with electrostatic spray nozzles (Electrostatic Spray Systems, Inc.) that introduced an electrical charge to fog droplets, causing the droplets to be attracted to leaf surfaces. The nozzles operated at an air pressure of 200 kPa and introduced water at a rate of about 48 $ml \cdot min^{-1}$. Computer-controlled fogging duration and intervals were set based on visual inspection for leaf wetness.

Experiments were conducted during Winter and Spring 2004. For the winter experiments, greenhouse stockplant shoots of *C. californica*, *G.* 'Evie', *G.* 'James Roof', *R. californica* 'Eve Case', *R. coulteri*, and *R. speciosum* were cut in mid-January to main branches and divided into leafy cuttings that ranged from semihardwood to tip cuttings. After the basal ends of the cuttings were dipped in Hormodin 1, 2, or 3 (0.1%, 0.3%, or 0.8% indole-3-butyric acid, respectively), the cuttings were stuck in flats of wet vermiculite and placed in the fog chambers, where bottom heat was maintained at 30 °C and air temperature ranged from 14 to 28 °C. Rooting was evaluated after 43–48 days.

For the spring experiments, cuttings of *C. californica, D. rigida, G.* 'Evie'*, G.* 'James Roof'*, R. californica* 'Eve Case', *and R. coulteri* were taken in May from stockplants in the greenhouse and lath house and from established plants growing in the U.C. Davis Arboretum. After basal ends of cuttings were dipped in Hormodin 1 or 3, the cuttings were stuck as described above and placed in the fog chambers or the mist bench. Bottom heat was 30 ºC. Air temperature in the fog chambers ranged from 15 to 46 ºC and 20–25 ºC in the mist bench. Cuttings were evaluated after 47-53 days.

RESULTS

In winter, neither the propagation chamber type nor the hormone treatment affected rooting percentage (Table 1). The data for *R. speciosum* are not in Table 1 because all the cuttings of this species rotted.

In the spring experiment, mean rooting percentages across all treatments ranged from 8.5% for *Dendromecon* to 75% for *Rhamnus* (Table 2). Rooting was significantly affected by propagation conditions: rooting percentage of plants propagated on the mist bench was higher than in either of the fog chambers (Table 3). This effect was particularly evident in *Carpenteria* and *G.* 'James Roof'. Interactions between species and propagation chambers were not significant for other species. It is likely that rooting in the electrostatic fog chamber was negatively affected by high air temperatures that occurred during a 5-day period when mechanical problems caused below-normal ventilation and water flow in the chamber.

The stock plant growing conditions had a significant effect on rooting percentage (Table 4). Cuttings from plants growing in the greenhouse were nearly twice as likely to root as those from either the arboretum or the lath house. However, many of the cuttings from plants growing in the arboretum were developing callus at the basal end and might have rooted if given more time.

Table 1. Rooting percentages for five difficult-to-root native California shrub species propagated in fog chambers at different IBA concentrations in Winter 2004.

	Standard fog			Electrostatic fog		
	Hormone concentration (%)					
Species	0.1	0.3	0.8	0.1	0.3	0.8
Carpenteria californica	82	83	86	65	82	84
Garrya elliptica 'Evie'	45	50	60	45	35	55
Garrya elliptica 'James Roof'	40	55	45	60	40	65
Rhamnus californica	63	83	87	87	73	67
Romneya coulteri	50	54	64	64	46	61

DISCUSSION

The reported advantages of fog over mist systems for rooting of difficult-to-root species (Hartmann et al., 2002) were not evident in this study. This may have been due to daytime air temperatures reaching 46 ºC in the fog chambers in the spring, whereas those in the mist benches averaged 21 ºC. Similarly, rooting percentage was higher during winter, when air temperatures in the fog chambers were moderate, than in spring, when temperatures were excessive. High leaf temperatures increase water loss and promote bud growth at the expense of rooting (Loach, 1988; Hartmann et al., 2002).

Fog generated from electrostatic spray nozzles was not more effective for rooting than fog from standard nozzles, although there were clear differences in fog droplet deposition. Fog in the electrostatic fog chambers was deposited on both upper and lower surfaces of leaves, but fog in standard chambers was deposited primarily on the upper leaf surface. Since most stomates are located on lower leaf surfaces, charged fog droplets could reduce water loss from cuttings and improve cutting water relations. This will be explored in future research.

In general, rooting was best from cuttings taken from container-grown plants in the greenhouse and it appears that rooting declined as the harshness of the environment for the stock plants increased. However, we only tested this during the spring. Since there are strong seasonal effects on rooting of many California native plants (Bart O'Brien and Ryan Deering, personal communication), studies with cuttings collected over a range of seasons are needed.

LITERATURE CITED

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Table 2. Rooting percentages for six difficult-to-root native California shrub species propagated in fog chambers or mist benches in Spring 2004.

Species	Rooting (%)
Carpenteria californica	39.0
Dendromecon rigida	8.5
Garrya elliptica 'James Roof'	18.5
Garrya elliptica 'Evie'	27.0
Rhamnus californica	75.4
Romneya coulteri	16.3

Table 3. Effect of propagation system on rooting percentages of six difficult-to-root native California shrub species in Spring 2004.

Propagation system	Rooting (%)
Mist bench	48.9
Standard fog	24.2
Electrostatic fog	19.3

Table 4. Effect of cutting source on rooting percentages of *Dendromecon*, *Garrya elliptica* 'Evie', and *G. elliptica* 'James Roof' in Spring 2004.

Propagation system	Rooting (%)
Greenhouse	26.6
Lath house	16.1
Arboretum	11.4