ing members of the plant world. California natives represent a rather untapped resource for us to explore.

The outlook for the future? Hopefully the nurseries growing a few natives at the present will have greater success in the future and will add to their list. Certainly research being undertaken by institutions such as the Saratoga Horticulture Foundation, the Santa Barbara Bontanic Garden and Rancho Santa Ana Botanic Garden, as well as our colleges and universities, will help us to solve the cultural problems we face. If these plants are to be a viable part of the nursery industry, it will take a commitment on the part of those of us in the industry. I hope that you will agree that California native plants are worth the effort.

CARBONATED MIST AND HIGH INTENSITY SUPPLEMENTARY LIGHTING FOR PROPAGATION OF SELECTED WOODY ORNAMENTALS

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Abstract. Injection of CO_2 to the mist water (CO_2 mist) promoted rooting of *Magnolia soulangiana*, *Magnolia sieboldii*, *Juniperus sabina*, and *Rhododendron* 'Anah Kruschke' Daily high intensity lighting with high pressure sodium (HPS) lamps for 16 hours promoted rooting of *Magnolia soulangiana* and *Rhododendron* 'Anah Kruschke' and inhibited rooting of *Juniperus sabina*, *Juniperus squamata* and *Rhododendron* 'May Day' These results are discussed in terms of photosynthesis, CO_2, light and water

REVIEW OF LITERATURE

Plant propagation involves a great number of plants in a small production area where use of controlled environment appears to be logical. Enrichment with CO_2 and/or high intensity lighting at the time of seeding plants has accelerated the growth of herbaceous and woody seedlings (2, 9, 10, 11, 19). Modification of environments for propagating cuttings has not been studied extensively.

Many plant species or cultivars (genotypes) are difficult or almost impossible to propagate by cuttings. Previous work (14) demonstrated that rooting was improved by CO_2 enrichment of the atmosphere or of the mist (CO_2 mist). A recent report (3) described the benefits of using high intensity lighting with herbaceous cuttings, but the effects of such lighting on woody cuttings has not been widely studied (1).

Experiments were initiated to investigate the effects of CO_2 mist and high intensity supplementary lighting on rooting of

selected woody ornamentals.

MATERIALS AND METHODS

Two identical greenhouse compartments were equipped with intermittent mist systems. The mist at 40 psi was automatically controlled by a finely meshed "leaf" (Mist-A-Matic) moving in response to weight of moisture on its surface. The cuttings in one compartment were treated with CO_2 mist containing 900 to 1200 ppm of CO_2 using a system described by Molnar and Cumming (14). The control compartment was misted with tap water containing 200 to 400 ppm of CO_2. Both compartments were lighted by 400 W SON/T high pressure sodium (HPS) lamps mounted 1.83 meters above the propagation bench which provided 4000 lx supplementary light.

Lighting was 12 hours per day (7 A.M. - 7 P.M.) for Experiment I and 16 hours (4 A.M. - 8 P.M.) for Experiment II. The air temperatures were set at 16°C (61°F) during the light hours and 10°C (50°F) in the dark. The rooting media were maintained at 21°C (70°F) with a heating cable. There were two experiments, with different lighting hours, rooting hormones, media and genotypes, as below.

Experiment I (1978-79). This experiment was conducted to examine the rooting response to CO_2 mist with daily 12 hours (7 A.M. - 7 P.M.) of lighting. Fifty cuttings were used for each treatment. Cuttings of *Rhododendron* were treated with 0.8% IBA in talc (Seradix) and other species with 0.3% IBA. The rooting medium contained equal volumes of sphagnum peat moss and perlite.

Experiment II (1979-80). This 2 × 2 factorial experiment was conducted with 2 levels of CO_2 (with and without CO_2 mist) and 2 levels of light (with and without HPS light). Each greenhouse compartment was divided into 2 sections with black plastic film. One section was lighted for 16 hours (4 A.M. - 8 P.M.) daily. The other section was not lighted. Each treatment contained 40 cuttings of each genotype except *Magnolia*. Cuttings of *Rhododendron* and *Ilex* were wounded on one side, while the others were not. All cuttings were dipped in 0.8% IBA in talc and inserted into rooting medium containing equal volumes of sphagnum peat moss, perlite and sand.

RESULTS AND DISCUSSION

Experiment I. In general, CO_2 mist increased the percentage rooting in English holly, *Rhododendron*, *Chamaecyparis*, *Juniperus* and Douglas fir. The quality of the root system in *Taxus* × *media* and Douglas fir was also improved by CO_2 mist (Table 1).

Table 1. Effects of CO_2 mist on rooting of *Taxus* × *media* 'Brownii' and *Pseudotsuga menziesii* '162'[1]

	− CO_2	+ CO_2
	Taxus × *media* 'Brownii'	
Average number of roots per cutting	2 4	4 4
Average root length per cutting (cm)	6 3	26 0
Average root fresh weight per cutting (g)	0 18	0 57
	Pseudotsuga menziesii '162'	
Average number of roots per cutting	1 8	2 6
Average root length per cutting (cm)	17 5	20 3
Average root fresh weight per cutting (g)	0 65	0 94

[1] 50 cuttings per treatment

Experiment II. The percent and quality of rooting due to CO_2 mist and HPS lighting varied between genotypes tested.

CO_2 Mist. The CO_2 mist increased percent and quality of rooting in *Magnolia soulangiana, Magnolia sieboldii* (Table 2), *Rhododendron* 'Anah Kruschke' (Table 3), *Juniperus sabina* (Table 4), and 2 cvs of *Ilex aquifolium. Juniperus squamata, Ilex crenata* and *Rhododendron* cvs. 'May Day' and 'Elizabeth' failed to respond to CO_2 mist.

Table 2. Effects of CO_2 mist and supplementary lighting with high pressure sodium (HPS) lamps on rooting of *Magnolia*[1]

	− CO_2		+ CO_2	
	− HPS	+ HPS	− HPS	+HPS
	Magnolia soulangiana			
Percent of cuttings rooted	47	100	100	100
Average number of roots per cutting	1 9	7.2	9 3	10 0
Average root length per cutting (cm)	10	42	60	71
	Magnolia sieboldii			
Percent of cuttings rooted	100	93	100	100
Average number of roots per cutting	7 7	6 5	10 3	9 3
Average root length per cutting (cm)	55	62	87	89

[1] 15 cuttings per treatment

Among the 10 genotypes listed, CO_2 mist promoted rooting in six and did not affect four. The improvement in rooting observed in this experiment was not to the same degree as previously reported (14). The CO_2 concentrations of 900 to 1200 ppm were lower than the previous study of 1500 to 1800 ppm. It is worthwhile to note that *Ilex crenata* rooted 95 to 98% without CO_2 and *Ilex aquifolium* rooted 36 to 86% with CO_2. It appeared that easy-to-root genotypes might not benefit from CO_2 mist while hard-to-root ones would. The present study also indicated that CO_2 mist increased rooting of many plant species in addition to those studied previously (14). This CO_2 response is considered commercially important and it was recently confirmed by a commercial operator (17).

HPS Lighting. The effects of HPS lighting were less evident

than those of CO_2 mist on rooting. The HPS light increased percent and quality of rooting of *Magnolia soulangiana* (Table 2) and *Rhododendron* 'Anah Kruschke' (Table 3). HPS light reduced rooting of *Rhododendron* 'May Day' (Table 3) *Juniperus sabina*, and *Juniperus squamata* (Table 4). *Magnolia sieboldii*, 2 cvs of *Ilex aquifolium*, *Ilex crenata*, and *Rhododendron* 'Elizabeth' did not respond.

Table 3. Effects of CO_2 mist and supplementary lighting with high pressure sodium (HPS) lamps on rooting of *Rhododendron*[1]

	$-CO_2$		$+ CO_2$	
	− HPS	+ HPS	− HPS	+ HPS
	Rhododendron 'Anah Kruschke'			
Percent of cuttings rooted	25	48	78	90
Average root ball diameter (cm)	0 6	1 3	2 4	3 9
	Rhododendron 'May Day'			
Percent of cuttings rooted	90	73	100	85
Average root ball diameter (cm)	5 2	2 5	5 6	3 6
	Rhododendron 'Elizabeth'			
Percent of cuttings rooted	95	95	100	93
Average root ball diameter (cm)	5 1	5.6	5 0	5 1

[1] 40 cuttings per treatment

Table 4. Effects of CO_2 mist and supplementary lighting with high pressure sodium (HPS) lamps on rooting of *Juniperus*[1]

	− CO_2		+ CO_2	
	− HPS	+ HPS	− HPS	+ HPS
	Juniperus squamata 'Meyeri'			
Percent of cuttings rooted	65	48	80	50
Average number of roots per cutting	4 4	3 2	6 9	5 0
Average root length per cutting (cm)	21 7	14 3	30.9	18 8
	Juniperus sabina 'Skandia'			
Percent of cuttings rooted	43	28	63	48
Average number of roots per cutting	1 6	0 8	6 4	3 1
Average root length per cutting (cm)	5 2	1.8	27 5	15 2

[1] 40 cuttings per treatment

Among 10 genotypes tested, rooting of two were promoted, five were not affected and three were inhibited by HPS. No general effects of light on rooting could be observed. This is in agreement with the results of many other investigators (1, 13, 18). High intensity lighting during the propagation of woody cuttings has not been widely investigated, but it has increased rooting of herbaceous cuttings (3).

The mechanism of root initiation is not fully understood and rooting response of cuttings is determined by a complex interplay of internal and environmental factors (7). The role of carbohydrates in rooting has been investigated (5, 12) and a proper balance between sugars and auxins for optimal production of

adventitious roots has been demonstrated (15, 16). Both CO_2 and HPS lighting are related to photosynthesis. CO_2 enrichment has increased photosynthesis (8). Photosynthetic activity of 22 species has been increased by HPS lighting (4). Inhibition of rooting by CO_2 mist and HPS is probably due to above optimal levels of carbohydrates (6), high foliar temperatures (2), or excessive dehydration (12). At the present, CO_2 mist offers an inexpensive and safe aid in rooting cuttings, while the value of HPS lighting in propagating woody cuttings is not so apparent

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MODERATOR GARTH HOKANSON: Let us have some good questions now for our speakers. Please give your name and use the microphone.

BRUCE MACDONALD: Chet Boddy, have you had any experience with leaf-bud cuttings of some of the more vigorous forms of mahonias?

CHET BODDY: I have experimented with a few. In the spring I read a paper that was published in *The Plant Propagator* and I thought I would try that. They rooted. Leaf-bud cuttings do root. The paper I read that gave me the idea was written by someone who had only one plant that he didn't want to destroy. I think if you have a big stock field and you are in commercial production the best thing is to go ahead and take tip cuttings — if you have the wood. They produce a better plant. But yes, those smaller leaf-bud cuttings will root. Not as well, but they will.

BRUCE BRIGGS: In using spores for fern propagation, you mentioned 5% Clorox for sterilization. How is this prepared?

BRUCE LANE: The way we fix our solution is to take the Clorox from the store and use 5% of that plus 95% water or one part Clorox to 19 parts water.

HUDSON HARTMANN: I would like to ask Dr. Lin if he ran a statistical analysis of his data and how many replicate cuttings he used?

W. C. LIN: On the second experiment, we used 5 cuttings of each replicate with 8 replicates so that would be 40 cuttings altogether. We have run the statistical analysis but we didn't have enough time to put it on the slides.

RALPH SHUGERT. Rick, If I understand right you are lifting your potted *Magnolia grandiflora* understocks in late October or early November.

RICK WELLS: Yes, and some of the cuttings originated at that same time. As the girls prepare the understock by removing the side growth, some of the cuttings are made at that time. Those then would be rooted and potted on the following June to August. Then they would be ready a year from that fall. So it is two years from the time we stick the cuttings to the time the understock is ready to graft.

RALPH SHUGERT: If I have my notes right, then, it takes

3½ years from the graft to the finished 5 gallon cans.

RICK WELLS: Correct.

RALPH SHUGERT: So we are now 5½ years from the time you stuck the cuttings which are going to be the understock to produce the grafts.

RICK WELLS: Correct

BILL CURTIS: Why do you graft your *Magnolia grandiflora* cultivars instead of rooting them as cuttings?

RICK WELLS: We have done some experimenting with rooting; however, the percentages have not been such that it is economical at this time. By grafting, we always get in the area of 80%. It just seems more economical to us right now to graft. Most of the cutting experiments that we have done have resulted in rooting percentages more like 30%.

BILL CURTIS: What time do you put in your cuttings for rooting?

RICK WELLS: They do best when started in winter, although we have tried them at all different times.

BILL CURTIS: Late in the winter?

RICK WELLS: No, more in the fall?

BILL CURTIS: I have grown *Magnolia grandiflora* cuttings for 30 years and there are many years that I have 90% to 100% rooting. We use a heel cutting taken from two-year-old plants. There is no problem with them; sometimes they root so heavily that we have to put them in two-gallon cans.

RICK WELLS: Do you have a secret?

BILL CURTIS: Our cuttings are about 4 or 5 inches long. Also we take all our cuttings from two-year-old plants. We use a high rooting temperature, 80°F. We use Hormodin No. 3 and we wound real heavy on the side. I think it is just a waste of time to graft them on seedlings because you get a good root system by cuttings. I know some people say that cuttings don't produce a good root system, so that is why they use a seedling — it has a better root system. But we had a bad wind storm several years ago that blew over timber but we never lost a magnolia tree in the field. So rooted cuttings do make a good root system. I cannot see why you waste your time grafting magnolias when the cuttings will root so easily.

RICK WELLS: I don't think I will try to respond to that.

JIM SAHLSTROM: I will go along with Bill; we will be glad to grow some of your native plants for you in Oregon.

VOICE: Dr. Lin, how old are the stock plants you used in rooting Douglas-fir? The general experience that we have had is

that trying to root cuttings from older Douglas fir is not very successful. Juvenile Douglas-fir, we had no problem at all. I am curious to know how old the plants were?

W.C. LIN: That is a good question; I don't know. The trees are about 6 to 8 feet tall. We took cuttings right from the middle portion, or the middle portion to the top. So that is all I can answer you, I am sorry I cannot say how old the stock trees are.

VOICE: I have another question for you. I noticed on your slides that the roots systems under your added CO_2 experiments were rather one-sided. In forest nurseries that are trying to produce seed orchard stock, it is really a problem. Nurserymen don't want to grow one-sided root systems. I wonder if you have had any other experience with them where you have obtained a more radially symmetric system?

W.C. LIN: We propagate just like any other ornamental plant. The flats are just about 3 inches deep. In order to sustain the cuttings, which are about 4 to 6 inches tall, we obviously have to set them deep, almost touching the bottom of the flat. When that happens, then the roots normally just grow in one direction in most cases. I don't know if that answers your question or not.

VOICE: I have a question for Dr. Lin. What material is the CO_2 chamber made of, and what is the purpose of the high pressure sodium lamp; is the reason being that naturally you have low sunlight in Vancouver Island, B.C. area?

W.C. LIN: When we grow our liners, we can increase plant growth by using 16 hours per day of high intensity lighting. Just like we did on the propagation. We feel the natural light in our area is too low for plants to function properly. The second clue is when we have the CO_2 as a raw material for the plant to utilize, to synthesize carbohydrates, we normally expect to have strong effectiveness of the light. If we just increase the raw material (CO_2), but don't provide the light energy for photosynthesis, we will not benefit from the added CO_2. Also the high pressure sodium lamp would provide some long-day effects. We combine those two together. Therefore we use 16 hours lighting per day.

GARTH HOKANSON: What is the chamber made of? Plastic or welded iron?

W.C. LIN: It is home-made. I couldn't remember the name of the material very quickly. Could be polyethylene or polyvinyl chloride (PVC).

VOICE: I wonder if Dr. Lin has done any work with the manipulation of his stock plants by extending the photoperiod and enriching the atmosphere and if that has had an effect on the rootability of the plants, or if you feel that is an area of

investigation for the future?

W C. LIN: We considered that, yes. We thought about that but due to our limitations we have only gone to the propagation stage and the stage of early growth of the container plants.

VOICE: Why do you use CO_2 in this case? What are you trying to achieve? Are you targeting for the carbohydrate content or are you targeting for the acidity of the water?

W.C. LIN: Our primary purpose is to increase the carbohydrate level. Because, many, many studies have shown there is a proper balance between auxins and carbohydrates which is essential for rooting. We feel after many months in the propagation stage under low light, the carbohydrates are obviously going to be depleted rather than increases. That is why we are using the CO_2. Hopefully we can maintain the carbohydrates in this way.

WESTERN REGION 1980 AWARD OF MERIT

Presented by Steve Fazio

The recipient of the Western Region's 1980 Award of Merit received his B.S. degree from the University of California in 1940 and a Ph.D. in Genetics from the same institution in 1952.

His professional career started as a plant breeder for the Grant Merrill Orchards, Red Bluff, California, shortly after he attained the Ph.D. degree. He was involved with this organization in the breeding of new peach and nectarine cultivars.

After 3 years of this work he returned to the University of California in 1953 where he became a staff member in the Department of Viticulture and Enology. In his early studies he was involved in virus problems with grapes, working with plant pathologists at the University of California. He soon became interested in the propagation of grapes and conducted many studies dealing with propagation by cuttings, budding, and grafting and in studying grape rootstocks. He also worked with his colleagues in the Department of Viticulture and Enology on the evaluation of wine grape cultivars in California.

In 1974, he was invited to visit the grape growing regions of Germany and France to study grape propagation as practiced in those countries.

Upon the organization of the Foundation Plant Materials Service on the University of California Davis campus he was appointed its manager on a part-time basis, handling this responsibility until about 1972 along with his research with grapes. He