FINAL REPORT
Saratoga Horticultural Research Endowment

Stock Block Management for Arboretum All-Stars Plants: Assessing Propagule Production Capacity

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Introduction

The collections and programs of The UC Davis Arboretum and Public Garden focus on sustainable horticulture practices and especially low water-use and regionally-appropriate plants for our Mediterranean climate. In 2005, we launched the Arboretum All-Stars program, an educational outreach program highlighting tough, reliable, low water-use plants that have been tested in the Arboretum (Cary and Zagory, 2007). It features California native plants as well as tough and adaptable non-natives, and many plants are selected for the program based on their value to birds, beneficial insects and native pollinators when they are incorporated in landscapes. The Arboretum All-Stars have caught the attention of California gardeners as a group of plants that can help them to easily create a more sustainable garden.

Plant selection and acquisition for low water-use landscapes is primarily based on what is available to California consumers through their local retail nurseries as well as a more restricted availability at seasonal sales held by botanical gardens and non-profit organizations such as the California Native Plant Society. For a plant to be adopted for use in commercial or wide-scale residential landscapes, it needs to be freely available in the wholesale nursery industry. Adoption of plant species by the California horticultural industry requires their adaptability to industrial-level nursery production practices. For a species to be grown and made available, it must be dependable in propagation and able to produce cutting stock in adequate quantities for an economy of scale. A roadblock to bringing plants into commercial production is that plant species, especially woody species, can be variable in their characteristics and in their response to nursery propagation practices. Plants selected for a superior character which is desired in the horticultural trade sometimes are not the easiest to reproduce asexually through cuttings (necessary to preserve the special characteristic in its progeny).

Goals/Objectives

"Hedging" is a practice used to manipulate plant growth, through repeated severe pruning and removing of the apical meristems of branches of the plant. This practice induces sprouting of sub-terminal buds, making the plant bushier with many side stems. This induced growth, from buds lower on the stem and closer to the crown, is known to induce in plants a state of "juvenility" in which the cuttings often form roots more easily. In this project we used this stock plant manipulation technique to determine if it would be useful in improving the propagation success of difficult-to-root All-Star species, to observe plant response, and to determine the

effect on the amount and quality of cutting material produced as well as the tolerance of the plants to these treatments.

The objectives of this project were to:

1. Conduct a propagation block management trial including the five species we began to augment in last year's cycle.
2. Establish two comparison blocks—one in the field and another in the greenhouse—and examine the effect of two different block manipulation pruning practices on the number and quality of cuttings produced and subsequent rootability.
3. Evaluate block manipulation success relative to quantities normally needed to create economic viability and document recommended techniques and results.

Plants selected were:

- *Koelreuteria elegans* ssp. *formosana* (syn. *K. henryi*)—a less brittle and more showy species that lacks the weediness of other *Koelreuteria* species and produces highly ornamental pink pods.
- *Osmanthus* × *fortunei* 'San Jose'—a superior and highly fragrant selection of this older hybrid
- *Chionanthus retusus* —a dioecious species that could produce a male clone of superior structure
- *Cercocarpus betuloides* ssp. *blanchae* —an evergreen, upright small tree with good disease resistance, excellent performance in low-water landscapes and attractive dark green foliage.
- *Ceanothus* × *pallidus* 'Marie Simon'—a beautiful, prolific pink-blooming ceanothus with red stems

Over the course of the study, we adapted our objectives and species selection based on realistic growing conditions for these difficult-to-root All-Star species. For instance, we replaced the originally selected *Arbutus andranchne,* which could only be found as seed and could not grow fast enough to be included in the study, with a select form of mountain mahogany *Cercocarpus betuloides* ssp. *blanchae.* In regard to hormone concentrations, we chose the most effective concentration for each species based on our local growing conditions and standard practices. The comparison of landscape and greenhouse blocks was only possible for *Osmanthus fortunei* 'San Jose', and with all other species, we were able to compare hedged and unhedged landscape grown forms. Additionally, there was a lack of data for *Ceanothus* × *pallidus* 'Marie Simon' since plants of unhedged material were unavailable and hedged plants did not sprout in time for inclusion in the study.

Despite these constraints, we were still able to generate meaningful results that now inform our nursery's propagation practices. See Attachment 1 for a summary of all trial results.

Individual species observations and results

Koelreuteria elegans ssp. *formosana*

Tip cuttings at 4,000ppm IBA hedged versus unhedged plants

Results:
The main difference in material from hedged and unhedged was that the hedged material had newer growth, so cuttings contained more softwood versus the consistent semi-hardwood of unhedged. Hedging the plants did not generate copious amounts of new growth. The only real advantage was that the trees were short and it was easier to collect material since a pole pruner was not needed as it was with the unhedged trees (Figure 1).

The cuttings from the hedged plants all completely rotted. In a handful, there were signs of callus tissue and small roots on one. But the rot was so extensive that it seems unlikely they could have developed roots and been to the point of repotting before they rotted out. The unhedged plants had more successful rooting and a few were repotted and moved into production (Figure 2).

This tree species did not adapt well to the process of hedging and continued to manifest strong apical dominance and few sub-terminal bud sprouts. Also, in July, hedged plants had sprouts that were very soft and were apparently more susceptible to fungal pathogens that resulted in rotting of cuttings. Cuttings from plants left unhedged were better hardened off in summer, did not show rot, and had a great proportion of rooted cuttings (Figure 3).

Hedging did not seem to have enough of a positive effect to recommend it as a treatment for improving propagation. Experimenting further with treatments of unhedged plants would be preferable as well as creating a larger stock of cutting sources to improve cutting availability.

Osmanthus × *fortunei* 'San Jose'

Landscape Grown Tip cuttings at 5,000ppm IBA: hedged versus unhedged plants

Results:
The cutting material on hedged plants was not uniform, with a mix of softwood and semi-hardwood and varying internode lengths, which made cutting lengths inconsistent. Unhedged plants had consistent material, all semi-hardwood.

Results were better from the cuttings taken from hedged plants, although the average value from hedged versus unhedged was similar and both treatments resulted in good quality roots. With the hedged treatment, however, it approached 50% success (a quality rating of 4). See Attachment 2 for rating system. The unhedged plants produced more consistently semi-hardwood cuttings but rooting quality was poorer, yielding only half as many 4 quality ratings.

Tip cuttings from Greenhouse Grown, hedged plants 5,000ppm IBA, mature growth (semi-hardwood) versus new growth (softwood)

Results:
Osmanthus × *fortunei* 'San Jose' was more tolerant of greenhouse culture than the other species in this trial. Extra cutting material was used to create another trial comparing softwood with semi-hardwood cuttings of greenhouse grown plants (Figure 4).

Unfortunately, the softwood cuttings mainly rotted, with less than half rooting. Those that did root had great root structure but the soft nature of the tissue seemed to make it more susceptible to fungal pathogens. The semi-hardwood (greenhouse grown, hedged, mature growth) yielded the best results seen in our trials of *Osmanthus* with 18 out of the 20 cuttings producing excellent root systems (rating of 4). Only one cutting did not root. The unusual size of the root masses required transplant into 4" diameter pots instead of normal 2" diameter pots (Figure 5).

This indicates that semi-hardwood cutting material has better rootability than softwood. Based on these results, we will keep our *Osmanthus* at the nursery hedged and use them for our cutting stock when semi-hardwood material is available. Greenhouse production of stock plants and then moving them outside to harden off is also recommended.

Chionanthus retusus

Tip cuttings at 8,000ppm IBA hedged versus unhedged

Results:
Cutting material collected from hedged plants was much more uniform than unhedged and mainly semi-hardwood with only slight variances in greater or lesser maturity of stems. Cuttings were thin in diameter. The unhedged plant was in fruit at time of cutting harvest, and it was difficult to find tip cutting material. On unhedged plants the cuttings were more varied in thickness (from thin to very thick) and also in internode length so uniformity of cuttings was poor.

Cuttings from the hedged plants produced a decent amount of callus tissue on the bottom, and one a small root. Callused cuttings were potted into 2" pots of soil to see if the callus tissue would develop into roots after repotting. The cuttings were still in good health at the time of reporting. Cuttings from unhedged plants had callus tissue on about half, but the material did not look healthy or worth repotting.

Tip cuttings at 10,000ppm IBA hedged versus unhedged

Results:
Cuttings from the hedged plants formed callus tissue in almost all cuttings, although the callus tissue was mostly small. Cuttings themselves did not look very healthy. Cuttings from unhedged plants at this concentration had little to no callus tissue.

Hedging appeared to increase callus formation of cuttings with 8,000 ppm IBA treatment indicating a possible change in physiological state of the plant as a result of hedging. Hedging *Chionanthus* also appears to have some impact on cutting quality and rootability. The higher

10,000 ppm hormone level had a reduced impact on callus formation, and further experimentation with hormone concentrations, media, etc. should be carried out on cutting propagation for this plant.

Cuttings from hedged plants were much easier to obtain and more uniform than from unhedged plants, and gave better callus tissue formation. Between the two concentrations, the lower 8,000ppm treatment resulted in better quality cuttings, perhaps in response to less toxicity of the lower hormone levels.

Cercocarpus betuloides var. blancheae

Tip cuttings at 10,000ppm IBA, hedged versus unhedged

Results:
Material from hedged plants was semi-hardwood that was fairly flexible. There was a lot of uniform cuttings material. Material from unhedged plants was harder to come by, also semi-hardwood but more varying in its maturity, with some material on the more mature side of semi-hardwood.

Cuttings from hedged plants did produce better quality cuttings with good amounts of callus tissue, and a few cuttings had well branched roots that were not brittle, so they were easy to repot without plant loss by root loss during handling. Root ratings were not the best, being assessed as a 3 rather than 4. Callus tissue wasn't as developed in most cuttings from unhedged, and there were fewer rooted cuttings although it is unknown if this is statistically significant. Unhedged cuttings resulted in more dead cuttings than hedged.

Tip cuttings at 12,000ppm IBA, hedged versus unhedged

Results:
Very similar to the results from 10,000ppm IBA, with slightly better results, with cuttings from hedged plants again showing a slight response.

Overall, the higher hormone concentration seemed to produce rooted cuttings with good structure and less brittle roots than prior experiments that used lower hormone concentrations. Although the hedged versus unhedged did not give greatly significant differences, the hedged plants did offer much more cutting material, and with success rates this low, it is an advantage over unhedged.

While none of the treatments provided the desired 4 quality rating (sufficient quality for commercial production), *Cercocarpus* produced more abundant and better quality cutting material with hedged versus unhedged plants. The increase in the number of rooted may not be sufficient to be statistically significant.

Discussion of Project Results

At the beginning of the trial a substitution was necessary to replace the originally selected *Arbutus andranchne,* which could only be found as seed, and was deemed too slow in growth to

yield adequate cutting material within the project period. It was replaced with a select form of mountain mahogany *Cercocarpus betuloides* ssp. *blanchae*, which has broader, shinier foliage than the species.

Plants potted and grown in the greenhouse remained evergreen for the winter of 2011-2012 but unfortunately succumbed to an attack of whitefly that deformed foliage and caused leaf drop. In an attempt to eliminate whitefly, a pesticide was applied that apparently many of the plants could not tolerate, resulting in leaf drop, complete defoliation of some plants and an additional delay in growth. The two species that were not affected were *Koelreuteria elegans* ssp. *formosana* and *Osmanthus* × *fortunei* 'San Jose'. An additional setback, resulting in lack of data for this selection was that *Ceanothus* × *pallidus* 'Marie Simon' did not produce sprouts after being hedged before we restarted the trials. The plants had flowers, and there was no new growth after flowering of adequate size to take cuttings. This cultivar was fully deciduous over that winter because of low temperatures.

The growth response of the different species to hedging varied greatly. In some cases it resulted in more uniform cutting material and in another (*Koelreuteria*), it did not. In addition, although hedging may give a more well-branched form that increases cutting material, pruning needs to be carefully timed to compliment each individual species' seasonal period of sprouting and stem extension. And as expected, with older unhedged plants, quantities of cutting material can be very low, requiring a greater number of individuals from which to cut.

Greenhouse growing of stock did not improve rooting response across the board of species. The plants included in this trial in general did not respond well to the higher light levels and temperatures of greenhouse culture. Plants elongated too rapidly, producing soft tissue that did not harden off and appeared to be more susceptible to pests and pesticide foliar toxicity. The only species that adapted to, and seemed to derive benefit for cutting success from greenhouse cultivation, was *Osmanthus* × *fortunei* 'San Jose,' which produced very good root systems rapidly from semi-hardwood plants after they were removed to a shade area and hardened off. Landscape grown blocks of plants were more compact than greenhouse ones while still producing useable cutting material.

Summary: General Recommendations for these species based on this and previous work

Cercocarpus betuloides ssp. *blanchae*

Previous work funded by the Elvenia J. Slosson Foundation (Zagory, et al, 2007) clearly demonstrated optimal success of cuttings of this subspecies taken in September/October and treated with 10,000 ppm IBA. Increasing hormone to 12,000 ppm did increase rooting success slightly although comparison of hedged versus unhedged in this study did not result in a dramatic increase of success. Hedging did, however, result in a greater abundance of good cutting material.

Koelreuteria elegans ssp. *formosana*

Previous propagation records indicate that the greatest rooting success for this plant is in June and July using 4,000 ppm IBA. There was no advantage of using hedging on this species demonstrated by this trial and results were better from unhedged growth.

Ceanothus × *pallidus* ‘Marie Simon’

Previous trials have shown positive results with 2,000 ppm IBA in May (80% cuttings rooted) as well as 5,000 ppm IBA in January (77%). In this trial, plants of unhedged material were unavailable and hedged plants had not re-sprouted in time for inclusion. Hedging needs to be carefully timed to provide material for future trials.

Chionanthus retusus

This species, when greenhouse grown, displayed the greatest damage from whitefly and greatest toxicity in response to pesticide application. Field planted specimens branched well but grew slowly relative to other species. Previous trials all showed negative results at a range of hormone levels, creating callus on the cuttings but no roots. According to Fred Davies Jr. at Texas A&M University, cuttings are difficult but can be propagated, “taking softwood cuttings in late spring, treating cuttings with 8,000 to 10,000 ppm IBA talc and propagating under mist, excellent rooting percentages can be obtained. Rooting improves when stock plants are kept juvenile.” Our experience was that even in hedged plants, cuttings formed only callus and no treatment was successful.

Osmanthus × *fortunei* ‘San Jose’

Old records showed that June propagation at 5,000 ppm IBA produced 50% rooting, while attempts in October and January were unsuccessful. Based on work at the UC Davis Arboretum and Public Garden Teaching Nursery, we recommend hedging, greenhouse culture of stock and hardening off of growth just prior to cuttings. This was the most successful.

Attachment 1: Summary of all Trial Results

ID#	Date	Name	Accession #	cutting type	Material From	Hormone	Qty	Notes	Date Potted Up	Rating	Notes	Average	percent success (rating of 3 or 4)
1A	7/2/2014	*Koelreuteria elegans* ssp. *formosana*		tip	Landscape Hedged	4,000ppm IBA	20	Softwood to semi-hardwood growth. Lenticils developing on lower portions of cutting material, but not as prevelent as unhedged. Longer internodes than unhedged on average. In general, just newer growth for the same time of year.	2/12/2015	1(x19), 2(x1)	All had ccompletely rotted. R2 did have three very small roots, but was rotted out as well.	1.05	0
1B	7/2/2014	*Koelreuteria elegans* ssp. *formosana*	A57.0146	tip	Landscape Unhedged	4,000ppm IBA	20	Semi-hardwood; lots of lenticils. Short internodes, mainly shorter points of new growth above hardwood on parent plants.	2/12/2015	1(x9), 2(x7), 3(x2), 4(x2)	R4s had very long, extensive roots with good branching. They had been left in containers longer than necessary, so some rrots looked a little old, but a few cuttings were pushing nice new roots. R2s with small to moderate callus tisuue.	1.85	20%
2A	7/29/2014	*Osmanthus* X *fortunei* 'San Jose'		tip	Landscape Hedged	5,000ppm IBA	20	Mix of softwood and semi-hardwood. Multiple branches coming off of tip, and some growth very new and other growth older (semi-hardwood). About one pair of leaves per cutting. Three to four defoliated nodes for semi-hardwood. Softwood cuttings varied. Some had three to four paris of leaves and long internodes. Other with shorter, thinner stems and two plus pairs of leaves.	3/17/2015	1(x6), 2(x5), 4(x9)	Really nice developed roots. R2s had good amounts of callused. These could have been potted up earlier. All cuttings alive except R1s all dead. New growth; really great results.	2.6	45%
2B	7/29/2014	*Osmanthus* X *fortunei* 'San Jose'	M05.9005	tip	Landscape Unhedged	5,000ppm IBA	20	Very uniform material; semi-hardwood. About one pair of leaves per cutting. Three to four defoliated nodes.	3/19/2015	1(x4), 2(x9), 3(x3), 4(x4)	Lots of callus tissue on R2s, some on their way to forming roots, just not quite there. Rs3 had thick singular long roots with slight secondary branching. R4s with good root branching.	2.35	35%
2C	7/3/2014*	*Osmanthus* X *fortunei* 'San Jose'		tip	GH Hedged, old growth	5,000ppm IBA	20	All growth semi-hardwood. Cutting material is very consistent, with two to three defoliated nodes per cutting, cutting length 2.5", whereas newer growth was inconsistent length and amount of nodes/length of internodes. Lenticils present, as well as thin layer of new bark beginning to form. *Cuttings taken and prepped 7/2/14, refrigerated overnight, and stuck 7/3	3/19/2015	1(x1), 3(x1), 4(x18)	The most incredible roots you could hope for. By far the best pot of Osmanthus cuttings I have ever potted up. New foliar growth, with many cutting pushing new branching from base. Outstanding.	3.85	90%
2D	7/3/2014*	*Osmanthus* X *fortunei* 'San Jose'		tip	GH Hedged, new growth	5,000ppm IBA	20	Most growth consisting of softwood growth. Some cuttings are softwood maturing into semi-hardwood. Mainly few lenticils present with the exception of the more semi-hardwood, which does have a moderate number of lenticils. Relatively short internodes on most material. Growth containing newest softwood tends to have longer internodes. *Cuttings taken and prepped 7/2/14, refrigerated overnight, and stuck 7/3	3/19/2015	1(x11), 4(x9)	R1s had mainly rotted away. R4s with very good root structure, very healthy.	2.35	45%
3A	7/29/2014	*Chionanthus retusus*		tip	Landscape Hedged	8,000ppm IBA	20	Semi-hardwood with new to moderate maturity. Most cuttings with two sets of leaves, and at least three defoliated nodes. Varying lengths of internodes resulted in some shorter cuttings and some much longer. Most material was very thin.	2/12/2015	1(x4), 2(x15), 3(x1)	Most cuttings had decent sized amounts of callus at the bottom of the cutting. Only one had a small root that had formed. Cuttings were still alive, but without leaves.	1.85	5%

3B	7/29/2014	*Chionanthus retusus*	M09.0244	tip	Landscape Unhedged	8,000ppm IBA	20	Tree was in fruit; fruiting stems removed from cuttings. Wide range of material from semi-hardwood to almost hardwood. Thin material to very thick. Most cuttings were short due to lack of long growth that had not already moved into hardwood. Although the hedged plants did give more uniform cuttings, this would nopt be the time of year to get uniform cuttings from an unhedged plant. One to two sets of leaves on most cuttings; leaves cut in half due to large size.	2/12/2015	1(x9), 2(x11)	Cuttings that weren't dead had similar to smaller amounts of callus than the hedged cuttings at same [iba]. A noteable difference is that not all cuttings with callues were alive, and buds on these cuttings were in generally poor health. I did not pot any of these up with the hopes that they may form roots although I was willing to take that chance with the hedged treatment (3A)	1.55	0
3C	7/29/2014	*Chionanthus retusus*		tip	Landscape Hedged	10,000ppm IBA	20	Semi-hardwood with new to moderate maturity. Most cuttings with two sets of leaves, and at least three defoliated nodes. Varying lengths of internodes resulted in some shorter cuttings and some much longer. Most material was very thin.	2/12/2015	1(x3), 2(x17)	The callus tissue on most of the rated 2 cuttings was small although a few had a fair amount. However, the material did not look worth repotting even though there was callus. So although there was better callus development at 8000 from the unhedged vs. the hedged, the best results were definitely hedged at 5000. Trying hedged at even lower concentrations would be a next step.	1.85	0
3D	7/29/2014	*Chionanthus retusus*	M09.0244	tip	Landscape Unhedged	10,000ppm IBA	20	Tree was in fruit; fruiting stems removed from cuttings. Wide range of material from semi-hardwood to almost hardwood. Thin material to very thick. Most cuttings were short due to lack of long growth that had not already moved into hardwood. Although the hedged plants did give more uniform cuttings, this would nopt be the time of year to get uniform cuttings from an unhedged plant. One to two sets of leaves on most cuttings; leaves cut in half due to large size.	2/12/2015	1(x10), 2(x10)	Cuttings still alive, but most had little to no callus tissue. Formation of callus tissue wass much les advanced/present than 3A.	1.5	0
4A	10/22/2014	*Cercocarpus betuloides* ssp. *blancheae*	M07.0521	tip	Landscape Hedged	10,000ppm IBA	20	Semi-hardwood, fairly flexible growth. Thin stems. Internodes at a good distance, cuttings fairly uniform in size. Good amount of lenticels on more mature material.	3/17/2015	1(x3), 2(x14), 3(x3)	Most cuttings still alive and. Rated 2's had moderate to well established callus tissue. R3s had fairly well branched roots that were not extremely brittle.	2	15%
4B	10/22/2014	*Cercocarpus betuloides* ssp. *blancheae*	M07.0521	tip	Landscape Unhedged	10,000ppm IBA	20	Semi-hardwood, less flexible growth than hedged plant, maturing to hardwood in some cuttings. Lots of lenticels. Fairly thin material.	3/17/2015	1(x6), 2(x12), 3(x2)	More dead cuttings than hedged, callus tissue on rated 2's was similar. Roots were fairly well-branched; easily transplanted.	1.8	11%
4C	10/22/2014	*Cercocarpus betuloides* ssp. *blancheae*	M07.0521	tip	Landscape Hedged	12,000ppm IBA	20	Semi-hardwood, fairly flexible growth. Thin stems. Internodes at a good distance, cuttings fairly uniform in size. Good amount of lenticels on more mature material.	3/17/2015	1(x5), 2(x11), 3(x4)	Most cuttings still alive. Rated 2s had moderate to significant amounts of callus tissue. Some with extremely high amounts. Roots were very well branched and not brittel (except one cutting was a bit brittle). Easy to transplant.	1.95	20%
4D	10/22/2014	*Cercocarpus betuloides* ssp. *blancheae*	M07.0521	tip	Landscape Unhedged	12,000ppm IBA	20	Semi-hardwood, less flexible growth than hedged plant, maturing to hardwood in some cuttings. Lots of lenticels. Fairly thin material.	3/17/2015	1(x8), 2(x10), 3(x2)	Similar to 4B. Concesus is that hedged and unhedged behave fairly similar, although hedged has a slight advatgae. However, hedged plants offered MUCH more cutting material that was easy to find, which is a definite benefit to production.	1.7	10%
Ceanothus 'Marie Simon'			This plant never pushed new growth after it was hedged last spring/summer. Not sure if this is a result of too much hedging, or just a reaction to hedging in general. There was no material to gather cuttings from as all material was in flower, never pushed, then went dormant. A possible conclusion would be that this plant is not suited for continual hedging in a "bare-bones" environment where it was located. Maybe it would behave										see comments

Attachment 2. Example of Root Rating System

0 = No roots, no callus

1 = No roots but callus present or small roots just beginning to emerge

2 = Very few roots (1-3) and small

3 = Long roots, sometimes unbranched or many shorter roots

4 = Well developed and often branched roots

Figure 1. Photo of K*oelreuteria elegans* ssp. *formosana* in greenhouse.

Figure 2. Photo of root growth from unhedged K*oelreuteria elegans* ssp. *formosana*

Figure 3: Comparison of landscape-grown, prepped cuttings of K*oelreuteria elegans* ssp. *formosana*

Photo 1: Unhedged *Koelreuteria* prepped cutting

Photo 2: Hedged *Koelreuteria* prepped cuttings

Figure 4: Comparison of softwood and semi-hardwood cuttings of greenhouse grown, hedged *Osmanthus* × *fortunei* 'San Jose'

Photo 1: new growth prepped cuttings of *Osmanthus*

Photo 2: mature growth prepped cuttings of *Osmanthus*

Figure 5: Comparison of roots from unhedged *Osmanthus* × *fortunei* ‘San Jose’ and hedged, semihardwood of *Osmanthus* × *fortunei* ‘San Jose’

Photo 1: Unhedged *Osmanthus*

Photo 2: Hedged, semihardwood *Osmanthus*

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