Scientific Name	Common Name
Arbutus unedo	Strawberry tree
Baccharis pilularis "Pigeon Point"	Coyote bush
Ceanothus 'Concha'	California lilac
*Ceanothus griseu*s 'Yankee Pt'	California lilac
Cistus 'Sunset'	Rockrose
Heteromeles arbutifolia	Toyon
Olea europea 'Manzanillo'	Olive
Pittosporum tobira	Pittosporum
Rhaphiolepsis 'Pinkie'	Indian Hawthorn
Rosmarinus officinalis 'Collingham Ingram'	Rosemary

Plant species used for the first screening. A total of 360 plants was required. This represents 10 species, 3 water qualities, 3 water application treatments and 4 repetitions per treatment. Given the redesign of benches, each future screening will require 720 plants.

Recycled Landscape Irrigation Water and Ornamental Plant Compatibility Study

Patricia Lindsey, M.A. Harivandi and Gail Setka

Recycled waters typically have higher total salts and specific ion concentrations exceeding those levels found in potable water, potentially having an adverse affect on plant appearance and health. Damage to some woody plant materials has been observed following the conversion of new and existing landscapes to recycled irrigation water in California landscapes. It is not yet clear if this damage can be attributed to reduced water quality, poor site cultural conditions and water management, or all of these factors. However, given the rapid rate of landscape conversions across California, it becomes imperative to separate out the relative influence of these factors.

By the year 2010, landscape irrigation will be the second largest user of recycled water (groundwater recharge being first). It is important to develop a list of recommended plants for new landscape sites on recycled water. Likewise, it is as critical to have an idea of the magnitude of potential problems with specific plant species and a better understanding of management issues when existing landscapes are converted to recycled water.

The effect of recycled waters on most woody plant species is currently unknown. Plant lists for tolerance or sensitivity to the high salts and specific ions found in recycled water are composed primarily of agronomic crop species or turfgrasses. Much of the salinity tolerance literature for woody plants that does exist is anecdotal in nature. The empirical studies with woody plants lack uniformity in research protocols, making it difficult to compare species response. As importantly, these studies frequently do not distinguish between plant response to irrigation waters that are foliar applied as opposed to soil applied.

A greenhouse study to evaluate a range of woody trees, shrubs and groundcovers for their tolerance to recycled water is currently in progress. As importantly, the longer term effects of recycled water on plant health and soil properties need to be evaluated in a landscape setting. Demonstration/research gardens have been designed and constructed in Marin (completed) and Sunnyvale (in progress) to study the effect of water quality on plant health, soil physical and chemical properties, and irrigation components.

Lastly, with the information from the plant screenings and the data and observations from a range of demonstration/research gardens across California, it is anticipated that specific recommendations can be made on plant selection, irrigation technology and site management strategies for landscapes utilizing recycled water. This information can then be developed into re-

source materials and a curriculum designed for a statewide shortcourse to extend this information to relevant professional groups - water purveyors, parks and recreation departments, landscape architects, arborists, landscape contractors and consulting horticulturists, and even homeowners.

Following are the detailed project progress report/ proposals for each part of this study: 1) screening studies for tolerance for recycled water, 2) the design and development of demonstration/research garden(s) and 3) educational outreach.

Part I - Screening Woody Plants for Tolerance to Recycled Irrigation Water

While a tremendous amount of research based information exists on the safe and effective use of recycled water in agriculture and on turfgrasses, analogous research for landscape plants, for the most part, does not exist. The urban landscape or even wildlife restoration projects, as distinct from agriculture, represent:

- A fundamentally different system, both in species composition and management.
- A level of plant diversity and integrated constituents that far exceeds that of homogeneous production systems.
- Plant species which are far more sensitive to the effects of recycled water.

An extensive literature review to identify woody ornamental plants tolerant of recycled water uncovered two major concerns regarding our current knowledge: 1) only a limited amount of empirical information is available for woody ornamental plant species and 2) the lack of uniformity in research protocols make if difficult to interpret and impossible to compare results even within the same plant species.

To address these concerns, a greenhouse screening methodology has been developed that sets experimental standards for evaluating the effect of water quality and water application method on ornamental plants. A study to measure the tolerance levels of 10 species of woody trees, shrubs and groundcovers to treatments of three water qualities (low, medium and high) applied in three ways (soil or foliar applied or both) as determined using a five increment visual analysis scale started in the spring of 1995. Water qualities were selected that bracket the full range of qualities presently being applied across California. At the conclusion of the ten week screening, measurements of plant size, growth rates, total leaf area and dry weight, root dry weight and tissue analysis of stem, leaves and roots for concentrations of sodium and chloride were taken. In addition, data was collected on soil EC, SAR, chloride, sodium and pH relative to plant tolerance.

The greenhouse setup was extensively redesigned and modified in the spring of 1996 to address two issues that came up during the first screening - 1) the need to increase the number of plant species screened at any one given time and 2) the need for more precise control over the consistency of the electrical conductivity of the water treatments during the 10 week screening trial.

The following represents the general procedures followed during the screening, with number 1 representing the subsequent redesign of the benches and water delivery system:

Screening Setup:

This now consists of four benches (2 benches per screening set). The will double the number of species studied, to 20 per screening. There are three 30 gallon storage tanks. Two are required to produce a concentrated stock solution of EIoaglands. One is a concentrated solution of sodium chloride. All three have submersible pumps. With a proportioner in each of the Hoagland tanks, an appropriate solution of Hoaglands for the potable water treatment (control) is created. Two proportioners are also located in the concentrated salt solution tank. These proportioners can be set to deliver whatever level of salt is required for the experiment.

Water Application Treatments:

- Soil applied only - all water qualities
- Foliage only and Foliage/Soil applied - Control water quality
- Foliage only and Foliage/Soil applied - Low/Medium salt level
- Foliage only and Foliage/Soil applied - High salt level

Each bench is sectioned into water application and water quality treatments using clear plastic partitions.

Water Quality Treatments:

- WQ1 (Water Quality l) = control = Hoagland solution EC= .8-1.2 dS/m

- WQ2 (Water Quality 2) = low/medium salt level--EC = 2 dS/m
  (close to EC of recycled waters produced in many recycled water plants)
- WQ3 (Water Quality 3) = high salt level--EC = 6 dS/m

Applying the Water:

- Apply to soil only - drip emitters 10 gal/hr for 10 minutes at 9am every morning
- Apply to foliage only - micro-sprinklers (two per section) for two minutes at 9am, 12pm, and 3pm. Foliage will be completely wetted throughout plant. Soil will be protected from saline water entry by plastic covers over tops of pots. Plant soil/roots will be watered by drip emitter with Hoaglands solution (WQ I)
- Apply to foliage and soil - same application method as above without pot covering

Analysis:

- Soil samples will be taken at week 0, week 5 and week 10 of study to follow soil quality. Soil will be analyzed for EC, SAR, chloride, sodium and pH relative to plant tolerance
- Health ratings (0-5 scale, 5 being healthy) will be taken every two-three weeks. After 10 weeks of study, plants will be harvested as leaves, stems and roots, dried and weighed. All stems, leaves and roots will be ground and digested to obtain an extract solution for chemical analysis of Na, Cl, Mg, and Ca.

Progress report for first screening:

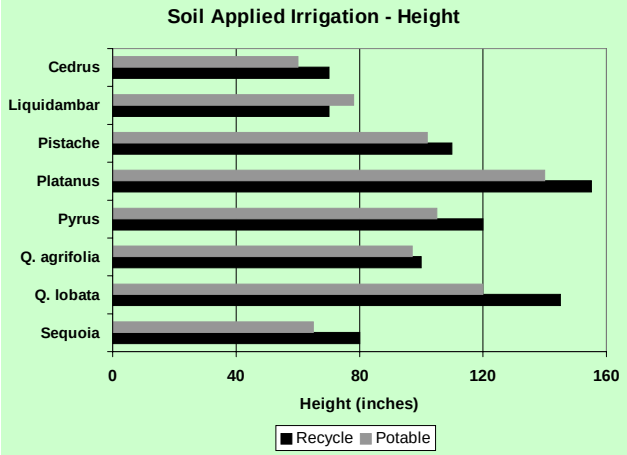
- Plants selected, ordered, received, repotted and place on benches by May 1995
- Treatment period started June 16, 1995 and completed August 25, 1995
- Harvesting (separation of foliage, stems, and washing of footballs occurred from 8/95 to 10/95
- Over 1,080 plant samples were obtained for analysis. Approximately 2/3 of the root samples remain to be ground and the remaining foliage and stem tissue has been ground and digested. The chloride testing is now in progress. Extracts have been obtained for all soil samples, and upon completion of spectrometer testing of the plant tissue, the soil will be analyzed.

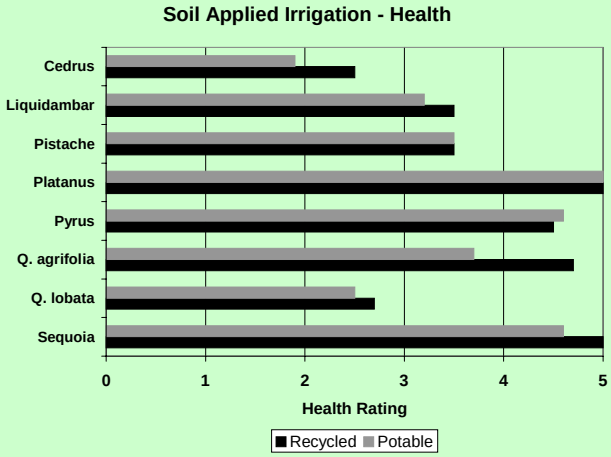
Preliminary results indicate that some species will undergo reductions in growth and appearance due to both water quality 2 and 3 (see graphs, next page). Likewise, several species seem resistant to any impact due to water quality. There were also observed levels of tolerance related to method of water application. The results from the tissue analysis for sodium and chloride coupled with the data on growth and appearance will identify those species sensitive to the foliar application of recycled water.

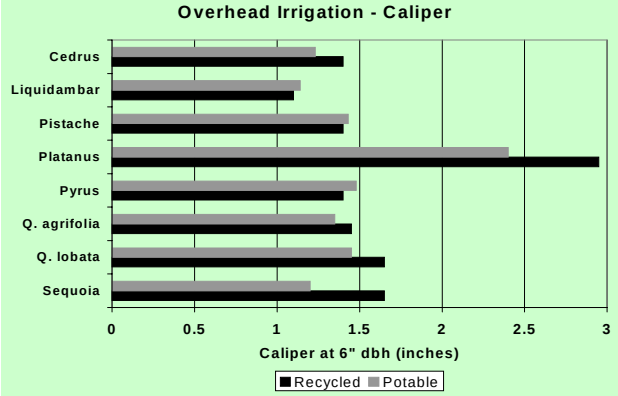
Part II - Evaluating the Long-Term Impacts of Recycled vs. Potable Irrigation Water on Plants and Soils in a Landscape Setting

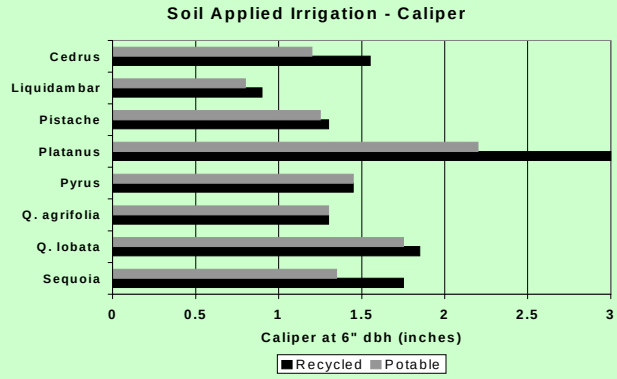
Over the last two years, an extensive field demonstration/research garden was designed and constructed in Marin County in response to community concerns regarding the impact of recycled water on landscape plants, soils and irrigation components.

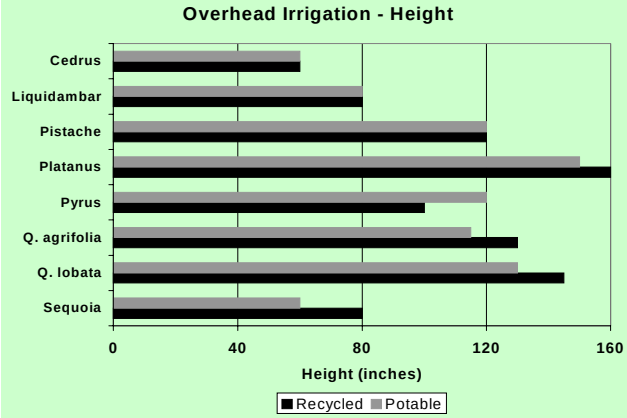
The total garden area is a little over 3/4 of an acre and divided into 32 separate blocks for experimental purposes. Representing 24 different plant species, the garden contains 128 trees, 480 shrubs, and 576 groundcovers. Plants were selected based on their varying responses to recycled water. The effect of water quality on plant health and soil physical and chemical properties is now being studied directly in the field using two water application methods: 1) foliar applied irrigation (overhead spray) and 2) soil supplied (drip or bubbler). The first data on plant growth and health along with tissue and soil samples was collected in the spring, summer and fall of 1995. While the data is still being analyzed, the graphs on the following page indicate some general trends regarding water quality, method of water application and species. In the graphs, the black bars represent recycled water, the gray potable. Graphs are presented for the trees only. Generally, for most species, the use of recycled water seems to produce a higher health rating, height and caliper. This could be due to the higher levels of total nitrogen in the recycled water. Interestingly, for many species, overhead irrigation seems to result in a higher height

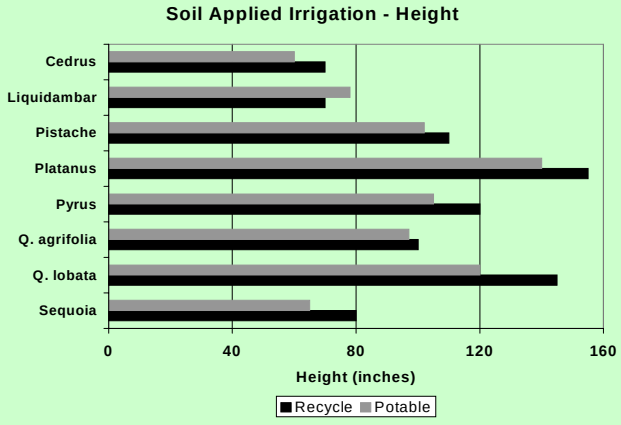












Graphs presented are for trees only. Generally, for most species, the use of recycled water seems to produce a higher health rating, height and caliper.

and caliper, regardless of water quality.

Starting in the spring of 1996, we have also been working with the City of Sunnyvale to develop a 2.7 acre demonstration research garden. The experimental design will be similar to that of the Marin garden, and while the data collected will be the same, the plant species will all be different. Data collection will start in the fall of 1996.

Part III - The Development of a Statewide Resource Manual and Workshop for Professional Groups Involved in Converting/Managing Sites on Recycled Irrigation Water

An ongoing educational outreach project has been developed in order to disseminate management guidelines specific to landscapes using recycled water. This educational project evolved from research currently in progress studying the effects of recycled water on ornamental plants, soils, and irrigation components. Given the increasing use of recycled water in the landscape, it becomes critical to separate out the relative influence of water quality, poor planting conditions, inappropriate cultural practices, and/or improperly designed irrigation systems on the health of landscape plantings. Research on the effects of recycled water on woody ornamental plants is now underway and will hopefully continue to generate extensive lists of recommended plants over the next several years. The challenge now is to effectively extend this information to interested professional groups.

The first objective of this project was to identify, evaluate and organize relevant research information and educational materials into a comprehensive technical resource manual. This manual provides needed guidelines on effective site management practices for landscapes using recycled water, practices that are based on sound horticultural principles and also incorporate new research-based information.

The second objective was to develop an educational curriculum for professional groups involved in the conversion/management of landscapes on recycled water. An intensive daylong workshop was designed utilizing this resource manual. Processes detailed in the workshop included recycled water production, service activation, site analysis, water quality evaluation, site water use, irrigation design and technology, plant selection, maintenance strategies, and effective approaches for successful landscapes. The workshop was divided into lecture, demonstrations and activity sessions. The first workshop was conducted twice in 1995 in Marin County and once in May of 1996 in the City of Sunnyvale. The Cities of Santa Barbara and San Diego have also expressed an interest in holding these workshops in the fall and winter of 1996. Additionally, discussions are underway with the WateReuse Association of California to develop this workshop and the resource materials into a statewide workshop to be held annually at UC Davis for water purveyors, parks and recreation departments, landscape architects, arborists, landscape contractors and consulting horticulturists.

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