Root Growth in Containers: Implications for Xeriscape and Restoration

Truman P. Young and Richard Y. Evans

Traditional horticultural settings are mesic. Water is supplied as needed to plants that may not be completely suited to the local environment. However there is an increasing preference for low maintenance landscaping, which in the western United States is best exemplified by xeriscape plantings. In areas where water is naturally a limiting resource, it makes sense to use plants that are adapted to low rainfall. Often these are native plants, although many non-natives serve this role well.

Superficially, plants well adapted to drought should be easy to establish under natural rainfall regimes. However, horticultural practices during production and initial establishment can hinder longer term survival in dry soils. In particular, the use of container-grown plants and the common practice of drip irrigation may cause plants to produce shallower roots (Fernandez et al. 1991, Welch 1997), which puts them at a disadvantage when left without irrigation (Welch 1997). These practices can prevent the production of deep tap roots in woody plant species for which they are typical, and this effect can last long after planting in a dry environment. "Indeed the root system of container-grown plants may never develop the same structure as the 'normal' system of direct sown plants" (Moore 1985). Occasional flood irrigation may produce plants better suited to dry conditions than the more regular drip irrigation so common in xeriscapes and restoration sites (Jeff Hartz, pers. comm.).

The 'weaning' of well-watered woody plants in xeriscape settings is a serious problem (Warren Roberts, pers. comm.). Two recent studies have shown the difficulties in transferring container plants to non-irrigated sites. Welch (1997) found that container-grown seedlings of big sagebrush had higher mortality and less growth than plants grown from seed, even with a six month 'advantage'. McCreary (1996) has shown that 1-year old container-grown plants of blue oak (*Quercus douglasii*) fared worse under natural rainfall than individuals sown from seed or grown in containers for only four months. Root morphology was also experimentally manipulated in this study, which surprisingly had little effect on field performance.

One of the most common xeriscape plants in the Central Valley of California is the native Valley Oak, *Quercus lobata*. There has been difficulty in establishing native oaks in non-irrigated (restoration) sites throughout California, although greater success is achieved when seedlings are mulched and protected from herbivory (Hall et al. 1992, Adams et al. 1992, McPherson 1993). Additional research on establishment of *Q. douglasii* has been carried out (McCreary 1996; McCreary & Tecklin 1993, 1994), although not in the context of container growth. Conversely, the effects of container growth (especially root circling) on subsequent establishment success has been examined, but only in the context of well watered sites (Harris et al. 1971, Arnold 1996). However, the role of maladaptive root formation due to horticultural practices has rarely been examined in the context of success in (or 'weaning' to) non-irrigated sites (McCreary 1996).

Figure 1. Valley oak field trial using 3 stock types (seed, 3-month-old and 1-year-old transplants) and 3 forms of irrigation (precipitation only, flood and drip).

We carried out a factorial experiment on the effects of container growth and drip irrigation on root morphology of *Q. lobata*, and their consequences for establishment in non-irrigated soils.

We set out to answer the following questions for *Q. lobata*:

1. How does container growth affect the formation

of the root system?

2. How do container growth and irrigation regime affect ultimate root architecture in xeriscape conditions?
3. How are these root architectures associated with survival and growth rate when planted into, or 'weaned' to, non-irrigated sites?
4. What alternative production methods ameliorate or eliminate these problems?

In addition, we will use this study to address additional propagation issues:

5. Does seed weight or seed quality affect seedling performance, and by how much?
6. How soon do *Q. lobata* roots reach the bottoms of short and tall containers?
7. How does container size affect greenhouse and field success?

Methods:

Seed study. We examined the relationship between acorn size, weevil exit holes, and acorn cracking and the germination, growth and initial survivorship of valley oaks. There was near failure of the valley oak acorn production in 1998, which also occurred in previous El Niño years.

Searches of over one hundred valley oak trees in the vicinity of the cities of Davis and Winters, California in the fall of 1998 failed to find a single seed. Commercial native plant nurseries and seed sources were experiencing similar problems. In October, we were fortunate to obtain approximately 500 *Quercus lobata* seeds from a commercial source (Mistletoe Seeds) collected near Los Robles, California.

The acorns were placed into cool storage until January 1999, when radicles began to emerge. On 21 January, each acorn was weighed to the nearest milligram and was scored for the presence of cracks and the number of weevil exit holes. In cracked acorns several splits in the acorn occurred at their distal ends. The acorns were then divided randomly into two groups. The first 162 acorns were planted in a field experiment, spaced 2m apart and covered with a thin covering layer of soil (~1cm). These seeds were monitored only for predation and germination. In a lathhouse, 272 acorns were placed onto the surface of standard potting soil in 6x6x25 cm pots with labels recording their weight and then placed on benches and watered regularly. A subset of the smaller acorns had been planted in a separate experiment and eaten by rodents, but the remaining seeds represented the full range of seed sizes.

From 4 February to 11 March, the lathhouse seeds were surveyed weekly for germination, survivorship and additional exit holes. As the seedlings grew, the bases of the pots were monitored for whether the roots had reached the bottom of the pot by a visual check of the holes at the base of the pots. The field plantings were surveyed for germination at regular intervals.

On 25 February (week 5) half of the lathhouse seedlings were randomly selected and transplanted into larger pots (15x15x40 cm). In the week of 11 March (week 7) all of the seedlings were measured for shoot height to the nearest cm. If there was more than one shoot, the tallest was measured. The shoot heights were measured again on Wednesday 21March (week 13).

Field trials of planting stock. We bought nursery-grown seedlings from a local producer. We grew our own three-month oak seedlings in the greenhouse in a factorial design, with pot depth as an independent variable using depths of 20 cm and 40 cm. Initial propagation in deep pots might increase survival in dry sites (Bainbridge et al. 1995), perhaps because it encourages the growth of tap roots.

Seedlings (including recently germinated seeds) were planted out during the winter/spring of 1999 on the fields of Environmental Horticulture. A random stratified design was produced with three blocks. Each block had three sub-blocks, each with a different watering regime:

1. No additional water (natural precipitation only)
2. Drip irrigation
3. 'Flood' irrigation (thorough soaking in a moated area 1 m around the seedling).

Within each sub-block, there are six plots, two of each seedling age. Within each plot, there are nine seedlings. For the three-month old seedlings, plants from large and small containers were alternated. At the time of planting all seedlings were watered once. All seedlings have been monitored monthly for growth and survival (Figure 1).

Results and Discussion

Seed study. Acorns in both greenhouse and field plantings had ~90% germination, if they survived predation. Larger seeds had a higher probability of germination and germinated earlier than smaller seeds. Larger seeds had greater shoot growth and earlier root emergence from the bottom of pots than smaller seeds. Seeds that had weevil infestation showed less shoot growth than seeds that were not infested. Cracked seeds germinated later and had later root emergence than seeds without cracks.

Seedlings transplanted into larger pots grew more than twice as fast as those remaining in smaller pots. Although seed size and condition were significantly correlated with seedling success in valley oaks, these effects were relatively small. Valley oak tap roots outgrow even larger containers within a few weeks, which may have negative effects on their long-term survival in xeric sites. The most cost effective planting may be to directly plant acorns without sorting by size or condition.

Field trials of planting stock. Many of the year-old stock planted in the field had their shoots eaten by hares in the first few weeks, but this only killed plants with less than 2cm of shoot remaining. Fence repair and hare "round-ups" slowly reduced this problem, and along with weed control (see below) virtually eliminated hare herbivory by the summer of 1999. Approximately 40% of the acorns planted in the field were eaten by rodents in the first few weeks, but there was no subsequent herbivory.

There was tremendous growth of weeds in the first few weeks after planting. In some areas the weeds approached 100% cover and were several feet high. The worst of these was yellow starthistle. Initially these were reduced by hand weeding, but later we used topical herbicide.

There was only moderate growth through September 1999. Irrigated plants grew more than non-irrigated plants. The two forms of irrigation (flood and drip) produced plants of similar size, suggesting that our attempts to provide relatively equal amounts of water were successful. The height differences among stock types (seed, 3 month, one year) in October 1999 were similar to initial height differences, suggesting that there was no disproportionate advantage to starting life larger.

Almost all summer mortality occurred in the non-irrigated plots. In these plots, mortality was several times higher among greenhouse stock than among seedlings that grew from acorns planted in the field (20-21% vs. 6%). Although there was far less mortality in the irrigated plots, all of this was restricted to greenhouse stock (2-5%). It appears that seed stock is far hardier than greenhouse stock, especially under water stress.

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Truman P. Young is Restoration Ecologist amd Richard Y. Evans is UC Cooperative Extension Horticulture Specialist, Department of Environmental Horticulture, UC Davis.