The Influence of Treeshelters and Irrigation on Shoot and Root Growth of Three California Oak Species[1]

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Abstract

Treeshelters are individual seedling protectors that can accelerate height growth of native California oaks. There is concern, however, that this growth may occur at the expense of the roots, resulting in poor long-term field performance. This study could detect no differences between protected and unprotected seedlings in shoot weight, root weight or shoot/root ratios after 4½ years, suggesting that shelters do not adversely affect balances between seedling shoots and roots. Shelters did, however, stimulate height growth and reduce initial stem diameter growth, resulting in tall narrow plants that might not be able to stand upright without staking if shelters are removed too early. This study also evaluated the effects of irrigation levels on growth of three oak species—blue oak (*Quercus douglasii*), valley oak (*Q. lobata*) and coast live oak (*Q. agrifolia*). There were no significant differences among irrigation levels, suggesting that, in environments similar to the study site or in areas with fertile deep soils, supplemental irrigation after initial establishment is not necessary. Finally, the extremely rapid growth of both the valley oak and coast live oak in this study indicates that these species show promise for planting in urban landscapes.

Introduction

During the past two decades there has been increasing public concern about conservation and management of native oaks in California. Poor natural regeneration of several oak species has been repeatedly identified as a problem. Until recently, however, relatively little was known or understood about the biology of California oaks in general or regeneration processes in particular. Concerns about regeneration have led to a number of studies aimed at developing successful procedures for artificial regeneration of native oaks (Adams and others 1991, McCreary 1989). However, most of this research has been conducted on relatively harsh rangeland sites, such as Sierra Foothill and Hopland Research and Extension Centers (SFREC

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and HREC). Consequently, there is little information about the best procedures for establishing oaks in landscape settings where opportunities for more intensive management are possible.

One device that has shown particular promise for establishing oaks on rangelands is the treeshelter (Costello and others 1996, McCreary and Tecklin 1997, Tecklin and others 1997). These are double walled translucent tubes that protect seedlings from a number of damaging animals. They also stimulate aboveground growth by changing the environment seedlings are exposed to, including higher levels of CO_2, higher temperatures, and increased humidity (Potter 1991). However, some feel these devices may produce "unnatural" plants that are ill adapted to survive after the shelters are removed. This is because plants in treeshelters tend to grow tall and thin and may be unable to stand upright when shelters are removed. It has also been suggested that treeshelters may cause a preferential allocation of photosynthate to shoots. As a result of such carbon allocation, plants may be out of balance and not develop sufficiently large root systems to support their tops. It is not known, however, if such imbalances occur or how long they might last.

Finally, most research on oak regeneration in California has been with blue oak. This species has been identified as having poor natural regeneration and since it is widely distributed, there has been great interest in determining why regeneration is inadequate and how to overcome this problem. However, in urban or landscape settings, other native oak species may be preferable for planting because they have the potential to establish more quickly and grow faster.

This research project was designed to evaluate the performance of three species of native oaks planted in a horticultural setting, provided different levels of irrigation, and either protected with treeshelters or left unprotected. Annual height and diameter growth were monitored for 4½ years and total root weight, total shoot weight and shoot/root ratio were measured at the end of the study.

Methods

This study was conducted at Bay Area Research and Extension Center (BAREC) in Santa Clara. This Center offers a much different environment than SFREC or HREC since it has deep, uniform, agricultural soils, providing an opportunity for high levels of management. The field site was tilled and all weeds removed prior to planting. The soil, which is over a meter deep, is classified as a Campbell silty-clay loam.

In January 1997, pregerminated acorns of blue oak (*Quercus douglasii*), valley oak (*Q. lobata*) and coast live oak (*Q. agrifolia*) were planted in a field plot consisting of 4 blocks, each with 72 planting locations. Each block contained three irrigation treatment groups (24 seedlings). Irrigation treatments were 0.50 ETo (reference evapotranspiration), 0.25 ETo, and 0 ETo (control). Reference evapotranspiration was determined by a CIMIS (California Irrigation Management Information System) station located at BAREC. During the middle of summer ETo averages about 4 cm per week at BAREC.

All seedlings were irrigated during the first growing season with sufficient irrigation to ensure establishment, but no irrigation was provided to controls thereafter. The pressure compensating drip irrigation system provided water to an area approximately 20 cm by 20 cm around each planting location once a week through 3.6 liters-per-hour drip emitters. Irrigation continued until the fall rainy period. Irrigation was initiated in subsequent years in the summer and continued until there was 5 cm of rain in the fall. For the 0.25 ETo treatment, 3.6 liters of water per week were provided. For the 0.50 ETo treatment, seedlings were given twice this amount.

Within each of the 24-seedling irrigation plots, acorns were spaced 1.2-m apart. Each plot was separated from other plots by 2.4 m to ensure that irrigation treatments did not influence seedlings in adjacent plots, and a buffer row of seedlings was planted around the entire perimeter of the study area. Within each irrigation plot were three pairs of four-seedling rows. Each pair was randomly assigned to be planted with acorns from one of the three species. In addition, one of these rows from each pair was randomly assigned to have a 1.2-m treeshelter placed over emerging seedlings, while seedlings in the other row were left unprotected. All acorns were planted within a 2-day period.

Height and Diameter Measurements

Seedlings began to emerge in March 1997. At the end of the year, the height of each surviving seedling was measured and recorded. Height was the distance from the base of the seedling to the end of the longest shoot held straight. At the end of 1998 and 1999, the height, as well as the diameter, of each seedling was measured. Diameter measurements were taken at the base of each seedling, approximately 2 cm above the ground.

Final field assessments were made in mid-2001. Height was measured in May. In contrast to previous measurements where the longest terminals were measured, by mid-2001, many of the coast live oak trees were so tall that it was not possible to measure them this way. Therefore heights for this species were recorded as the distance from the base of the tree to the tallest portion of the plant. Diameters for all species were measured as before.

Root Excavation and Measurements

An objective of this study was to determine how shelters and irrigation affect root development and, in particular, whether treeshelters increase shoot growth at the expense of root growth. To determine this, we excavated, weighed, and measured root systems. However, since excavations are difficult, expensive, and time consuming, we excavated only a sub-sample of saplings in the study. We excavated all surviving saplings in one of the four blocks. Unfortunately, we were also constrained by the fact that one of the species, coast live oak, is susceptible to a new and potentially devastating disease called Sudden Oak Death, caused by the pathogen *Phytophthora ramorum*. Since BAREC is located in one of the infected counties, there was a quarantine on movement of coast live oak plant parts outside the county. Since our root evaluation procedures required us to take all of the harvested trees back to Sierra Foothill Research and Extension Center in Yuba County to dissect, measure and weigh, we elected to concentrate our root excavation and assessment on blue oak and valley oak and not evaluate the roots of coast live oak.

A backhoe was used excavate a 1.2-m deep hole on either side of each sapling, approximately 1.2 to 1.8-m from the trunk. The narrow bucket of the backhoe was used to carefully reach into the root zone and loosen the soil. The trunk of the sapling was then secured to a chain, which was hooked to the bucket of the backhoe. The bucket was rocked back and forth to loosen the soil in the rooting zone, and finally the chain was raised slowly, lifting the sapling and pulling it out of the ground. This worked quite well and seemed to provide a good, though not complete, recovery of roots. We estimated that approximately 10 percent of the roots was left behind, based on where and how thick some of the roots were that broke off. However it was not possible to accurately estimate how many of the finer roots were not recovered. In several cases, more roots broke and remained in the soil than we felt were acceptable; we excluded these from our sample.

Excavated trees were brought to SFREC, air dried in a warehouse for approximately two weeks, and then cut at root crown (the ground line), and separated into shoots and roots. These were placed in a drying oven for 5 days at 70°C. Prior to drying, all woody material was cut up into 10 to 15-cm segments. Dry weights for shoots and roots for each tree were recorded and shoot/root ratios were calculated.

Prior to drying and weighing, the diameters of the roots at various depths were also measured, and the roots were separated into various fractions (i.e. upper tap root, lower tap root, lateral roots) for weighing. In this paper we only report on total shoot and root weights and shoot/root ratios. A subsequent paper will describe root size and distribution in greater detail.

Statistical Analysis

Field data including survival, height and diameter were analyzed for a doubly nested, randomized block design, with irrigation levels as main plots, species as sub-plots, and protection treatments as sub-sub-plots. The data for these analyses were averages of the four-seedling rows within each block, irrigation treatment, species and type of protection (treeshelter or control).

We did not have enough observations to statistically analyze the shoot and root weight data as above, since only 31 sample trees were recovered with useable, excavated roots. We therefore analyzed shoot weights, root weights and shoot/root ratios for treatment effects using one-way analyses of variance.

Results

Survival

There were no significant differences in survival among any treatments during any year of the study. Average survival at the end of the first year (1997) was 82 percent, but remained fairly constant thereafter, falling to 79 percent by the last evaluation in 2001 *(table 1)*. One factor that appeared to contribute to initial mortality was that in some treeshelters rainwater did not drain adequately and some tubes filled several inches with water. When we observed this, we made holes in the bottoms of the shelters to drain the water, but there was probably some acorn mortality due to poor drainage.

Table 1—*Survival (pct) of acorn plantings for different species and treatments between 1997 and 2001.*[1]

	Survival '97	Survival '98	Survival '99	Survival '01
Species				
Blue oak	75	75	75	74
Valley oak	82	81	81	80
Coast live oak	88	84	88	83
Protection				
Treeshelters	81	80	80	80
Control	82	81	81	81
Irrigation				
No water	78	77	78	76
0.25 evapotranspiration	85	84	85	83
0.50 evapotranspiration	81	79	80	78

[1] There were no significant differences in survival in any year among species, protection treatments or irrigation treatments. Some survival percentages increased between 1998 and 1999 because of resprouting from apparently dead tops.

Height

Significant differences in height were found among species in each year of the study. During the first and second years (1997 and 1998), valley oaks and coast live oaks were significantly taller than blue oaks, but not different from each other *(table 2)*. By the last two years, there were significant differences between all three species, with coast live oaks the tallest, valley oaks next, and blue oaks the shortest.

Trees in treeshelters were significantly taller than trees without shelters in every year of the study. However, on a percentage basis, these differences tended to decline over time. There were no significant differences in height among irrigation treatments during any year of the study.

Table 2—*Average height (cm) for different species and treatments between 1997 and 2001.*[1]

	Height '97	Height '98	Height '99	Height '01
Species				
Blue oak	41 a	99 a	171 a	204 a
Valley oak	91 b	156 b	213 b	258 b
Coast live oak	75 b	159b	256 c	329 c
Protection				
Treeshelters	89 a	167 a	240 a	288 a
Control	50 b	108 b	187 b	240 b
Irrigation				
No water	63	127	200	244
0.25 evapotranspiration	67	141	211	269
0.50 evapotranspiration	77	145	229	279

[1] Within treatments (irrigation and protection) and years, heights with different letters are significantly different by a Fisher's Protected Least Significant Difference (LSD) Test. There were no significant differences in any year among irrigation treatments.

Diameter

Differences in diameter among species followed a pattern similar to that for height. For every annual evaluation, there were significant differences among species with coast live oaks having the largest diameters, followed by valley oaks and blue oaks *(table 3)*.

Table 3—*Average diameter (mm) for different species and treatments between 1997 and 2001.*[1]

	Diameter ’98	Diameter ’99	Diameter ’01
Species			
Blue oak	11.5 a	19.9 a	34.1 a
Valley oak	16.1 b	25.1 b	42.0 b
Coast live oak	22.7 c	42.3 c	77.1 c
Protection			
Treeshelters	14.9 a	26.8 a	46.9 a
Control	18.6 b	31.4 b	55.2 b
Irrigation			
No water	15.5	27.0	45.1
0.25 evapotranspiration	16.5	28.9	52.1
0.50 evapotranspiration	18.2	31.4	54.6

[1] Within treatments (irrigation and protection) and years, diameters with different letters are significantly different by a Fisher’s Protected Least Significant Difference (LSD) Test. There were no significant differences in any year among irrigation treatments.

Each year there were also significant differences between trees protected with treeshelters and those unprotected. However, in contrast to height, treeshelters produced plants with smaller stem diameters. As with all other variables, there were no significant differences in stem diameter among irrigation treatments.

Shoot and Root Weights

Valley oaks grew considerably larger than the blue oaks, and consequently, had significantly greater shoot and root dry weights. However there were no significant differences in shoot/root ratio between species. In addition, no significant differences in shoot dry weight, root dry weight or shoot/root ratio between irrigation or protection treatments were found *(table 4)*.

Interactions

There were several significant interactions in the analyses of height and diameter. In most cases this was because coast live oak had less of an increase in height for trees in treeshelters than the other two species. This species also had a greater decrease in diameter for trees in treeshelters. The only other significant interaction was between irrigation and species for the final assessment of diameter: the rankings of species were the same for each irrigation treatment, but the relative values were different.

Table 4—*Average shoot weights, root weights and shoot/root ratios for saplings harvested in July, 2001.*[1]

	Shoot wt. (gm)	Root wt. (gm)	Shoot/root ratio
Species			
Blue oak	945 a	742 a	1.32
Valley oak	2,100 b	1,393 b	1.55
Protection			
Treeshelters	1,451	987	1.52
Control	1,577	1,154	1.31
Irrigation			
No water	1,901	1,316	1.27
0.25 Evapotranspiration	1,445	953	1.60
0.50 Evapotranspiration	1,160	947	1.30

[1] There were significant differences in shoot weight and root weight between valley oak and blue oak saplings by a Fisher's Protected Least Significant Difference (LSD) Test. There were no other significant differences.

Discussion

In several studies treeshelters have been found to increase the growth of native California oaks (Costello and others 1991, McCreary and Tecklin 1997, Tecklin and others 1997). In two trials with coast live oak and valley oak, however, Burger and others (1996 and 1997) reported that while plants in treeshelters initially grew taller, by the second year there were no significant differences in height compared with unsheltered plants. Burger and others (1992) also reported that for oaks grown in containers for 2 years in a nursery, treeshelters reduced root dry mass, root/shoot ratio, total root length, and total root weight for valley oaks, as well as above-ground biomass for valley oak and coast live oak. However these studies were of relatively short duration and ratios might have changed if the plants were observed longer. Ponder (1996), for instance, found that tree-sheltered northern red oak (*Quercus rubra*) seedlings harvested 3 years after outplanting in forest openings had both higher stem and root weights than seedlings not protected with treeshelters.

In this study, treeshelters promoted height growth for all species, but produced smaller stem diameters. As a result, shoot dry weight was not significantly different between protected and unprotected plants. Total root weights were similar and, as a consequence, there were no significant differences in shoot/root ratios. Treeshelters therefore did not cause a preferential distribution of photosynthate to top growth. On the other hand, it is clear that treeshelters did alter shoot morphology by creating trees that were taller, but with thinner trunks. Results indicated, however, that this characteristic diminished over time. This is very consistent with a study conducted recently at Sierra Foothill Research and Extension Center with several sizes of treeshelters (McCreary and Tecklin 2001). The key benefits of shelters, therefore, are protecting plants from damaging animals and promoting rapid initial height growth. These are important factors in a number of landscape situations, as long as the shelters are left in place long enough for the plants to develop sufficient girth to become self-supporting.

There were no significant differences for any variable among irrigation treatments. We believe that one of the main reasons we did not observe differences was the fact that this study overlapped an El Niño period in California when annual precipitation was well above normal. As a result, plants in all treatments probably had adequate natural water for near maximum growth.

Rapid growth of both valley oak and coast live oak was notable. Even though native California oaks have a reputation of growing slowly, coast live oak averaged well over 3.3 m (10 feet tall!) after 4½ growing seasons, and valley oaks averaged 2.6 m, with some plants of both species nearly double these averages. Even after the first growing season, many seedlings from these two species (especially those in treeshelters) were over 2-m tall after being planted as acorns. Clearly, both of these species show great promise as landscape plants due to their good survival and rapid early growth.

Conclusions

Results indicate that valley oak and coast live oak can grow rapidly when planted from acorns in good quality soils. Protecting these species, as well as blue oak, with treeshelters promotes rapid initial height growth, but reduces stem diameter growth. As a result, shoot weights were similar after 4½ years for protected and unprotected trees. There was no evidence that treeshelters caused the trees to grow more shoots at the expense of roots since we found no differences in total root weights or shoot/root ratios between protected and unprotected plants.

We also could detect no differences in variables for plants provided different irrigation regimes. Although this finding suggests that normal rainfall is adequate to establish young oak seedlings, irrigation effects may have been masked by high moisture levels in the spring resulting from El Niño.

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