REFEREED RESEARCH ARTICLE

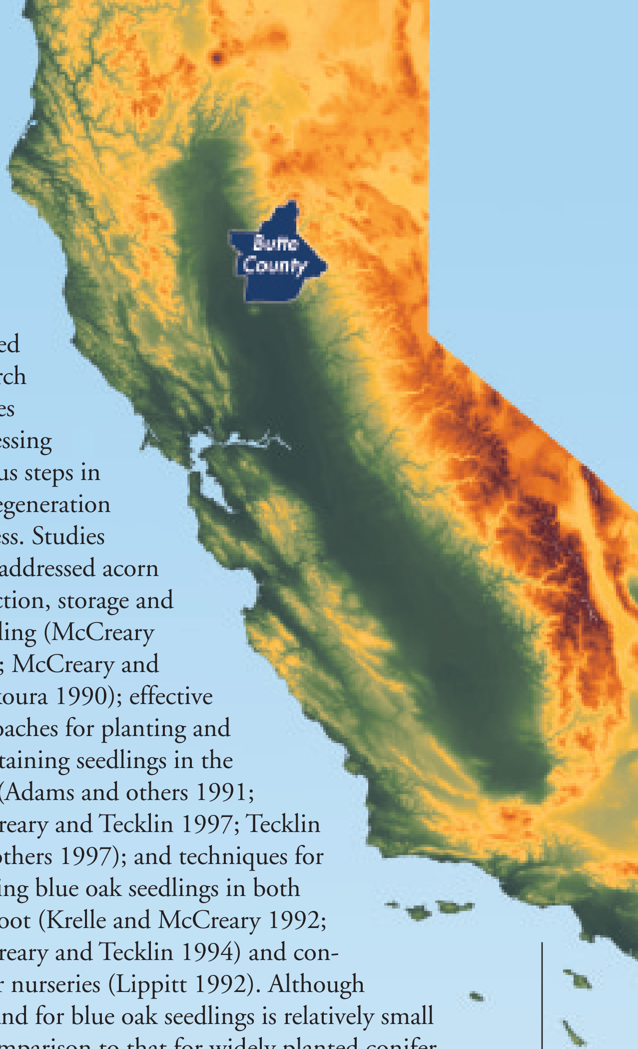
Blue Oak Mini-plug Transplants:

How They Compare to Standard Bareroot and Container Stock

Douglas D McCreary and Laurie Lippitt

A blue oak growing in the upper Sacramento Valley

Photo by Douglas D McCreary



Abstract

Blue oak (*Quercus douglasii* Hook & Arn. [Fagaceae]) is a widely distributed California oak that is regenerating poorly in portions of its range. Recent concern over habitat loss in blue oak woodlands has prompted efforts to regenerate this species artificially. Our study examined whether a relatively new stock type called mini-plug transplants would perform better in the field than conventional bareroot and container plants. Our results suggest that thought it is possible to produce blue oak mini-plug seedlings with large fibrous root systems, field performance was similar to other stock types that can currently be produced more economically.

KEYWORDS: Fagaceae, *Quercus douglasii*, artificial regeneration, California, woodlands

NOMENCLATURE: ITIS (1998)

Poor regeneration of several species of native California oaks has been a concern for the past 2 decades. This concern has been exacerbated because oak woodland habitats are increasingly threatened by firewood harvesting, agricultural conversions, and residential and commercial developments. To ensure that California's native oaks can be managed on a sustainable basis, researchers have sought to learn what is responsible for poor regeneration and develop successful artificial regeneration techniques.

As opposed to a single causal agent, several factors, varying in degree based on location, contribute to inadequate recruitment, including herbivory from livestock (Swiecki and others 1997), dry soils associated with changes in ground flora from predominantly perennial bunch grasses to introduced Mediterranean annuals (Welker and Menke 1987), high levels of damage from deer and rodents (Borchert and others 1989), and changes in fire frequency (McClaran and Bartolome 1989).

Blue oak (*Quercus douglasii* Hook & Arn.[Fagaceae]) is a widely distributed deciduous white oak that is regenerating poorly in many locations (Muick and Bartolome 1987). Endemic to the state, this species grows primarily in the foothills surrounding the Central Valley. Bolsinger (1988) estimated that the blue oak forest type occupied 1.2 million ha (2.9 million ac)—by far the greatest area for any hardwood type in California. Although blue oak has little commercial value other than for firewood, it provides vital habitat for numerous wildlife species and is highly valued for aesthetics. However, until fairly recently, relatively little interest existed in studying this species or developing successful regeneration techniques. Growing concern about habitat loss in blue oak woodlands has resulted in public support for planting and conservation efforts and funding for studies investigating blue oak's ecological role and biological requirements.

Interest in developing practical methods for regenerating oaks artificially has spawned a wide range of applied research studies addressing various steps in the regeneration process. Studies have addressed acorn collection, storage and handling (McCreary 1990; McCreary and Koukoura 1990); effective approaches for planting and maintaining seedlings in the field (Adams and others 1991; McCreary and Tecklin 1997; Tecklin and others 1997); and techniques for growing blue oak seedlings in both bareroot (Krelle and McCreary 1992; McCreary and Tecklin 1994) and container nurseries (Lippitt 1992). Although demand for blue oak seedlings is relatively small in comparison to that for widely planted conifer species, production has been increasing in recent years.

Although bareroot and container stock types have performed adequately after outplanting, we were interested in evaluating a relatively new stock type, the "mini-plug transplant." The mini-plug production system was first tested for conifers in the Pacific Northwest. The potential advantages of mini-plugs were that a more fibrous root system could be produced, 2 crops could be grown in a single year, and this seedling type required the shortest production cycle of any transplant stock (Hahn 1990; Tanaka and others 1988). However, this system required close monitoring of seedling morphology and physiology in both the container and bareroot phases of production.

Mini-plug seedlings grow for several months in relatively small, shallow containers, and are then transplanted to bareroot nursery beds. While in containers, seedling roots grow rapidly, but repeatedly air-prune due to shallow container depth. As a result, a highly branched root system with numerous growing tips develops. When mini-plugs are transplanted to bareroot beds, seedlings develop more fibrous root systems than conventional stock types. With an increased rooting area, they may be able to access more soil moisture and therefore survive and grow better in the Mediterranean climate of California's blue oak woodlands, characterized


Photo by LA Moran Reforestation Center

Figure 1 • A 5-mo-old mini-plug blue oak seedling ready for transplanting to a bareroot bed.

by a lengthy interval of hot, dry weather often extending from April to October.

Field performance of mini-plugs has generally been favorable. Tanaka and others (1988) reported that Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco [Pinaceae]) mini-plug transplants performed as well or better than several other bareroot and transplant stock types at a majority of sites in a large-scale outplanting in Oregon and Washington. Genere (1998) also found that Douglas-fir mini-plug transplants grown for 2 y in bareroot nursery beds (MP+2) performed better in the field than conventional bareroot stock on 2 of 3 sites, but mini-plug transplants reared for only a single year in bareroot beds (MP+1) performed poorer than controls on all sites.

Rose and others (1993) compared Douglas-fir mini-plug transplants (MP+1) with 2+0 bareroot seedlings (2 y in the same seedbed) and 1+1 bareroot transplants (1 y in a seedbed and then transplanted into another bed) and reported that mini-plugs performed as well as the more traditional stock types. They also noted that when these 3 stock types were exposed to the maximum moisture stress conditions tested, mini-plug transplants maintained the most favorable water relations and continued actively growing for a longer interval. Finally, Scarett (1989) examined growth of mini-plug black spruce (*Picea mariana* (Mill.) B.S.P. [Pinaceae]) seedlings transplanted after 8 wk to larger paper pots, and found that though transplanted seedlings were smaller than seedlings grown for the entire 14-wk interval in larger pots, they were far larger than seedlings kept in the small pots (which were only 1.3 cm (0.5 in) diameter by 4.4 cm (1.7 in) deep) the entire time. Scarett pointed out that an economic benefit of this system was that intermediate transplanting had the potential to ensure full stocking within containers.

Our objective in this study was to evaluate the mini-plug approach for growing blue oak seedlings, and compare field performance of this stock type with that of 1+0 container seedlings and conventional 1+0 and 2+0 bareroot nursery stock.

Materials and Methods

We collected acorns at 1 location in Butte County, California, that is approximately 100 m (328 ft) higher in elevation and 25 km (16 miles) farther north than the planting site. The 1+0 and 2+0 bareroot seedlings were sown at the California Department of Forestry and Fire Protection (CDF) nursery in Magalia in late fall, 1990 and 1989, respectively. Seedlings were undercut twice during their first growing season.

Container and mini-plug seedlings were sown at CDF's LA Moran Reforestation Center in Davis in early December 1990. Mini-plug seedlings were grown 5 mo in 3.8 x 3.8 x 7.6 cm (1.5 x 1.5 x 3 in) open ended square containers on raised racks to promote air pruning of roots (Figure 1). In early May 1991, seedlings were taken to the Magalia Nursery and transplanted into standard bareroot nursery beds and grown until the following winter. Due to their root morphology at planting, they were not undercut after transplanting. Container seedlings were grown in 6.4 x 6.4 x 20 cm (2.25 x 2.25 x 8 in) open-ended square containers (Monarch Mfg Inc, 13154 County Rd 140, Salida, Colorado 81201).

Mini-plug transplants and bareroot seedlings were lifted from the nursery in December 1991. In January 1992, we planted 4 blocks at the Sierra Foothill Research and Extension Center (SFREC), located in the low-elevation Sierra foothills, approximately 30 km (19 miles) northeast of Marysville, California. Each block contained 2 randomly located rows of 8 seedlings from each stock type (64 seedlings per block). Seedlings were planted on 2.1-m (7-ft) centers after placing a 21-g (0.74 oz) fertilizer tablet (20N:10P_2O_5:5K_2O formulation) in the bottom of each 25 to 30 cm (10 to 12 in) deep planting hole. We controlled weeds for the first 6 growing seasons (1992–1997) with a combination of herbicides (glyphosate) and mechanical removal. Individual seedlings were not protected, but the entire plot was fenced to keep out deer and livestock.

TABLE 1

Average yearly survival (%) for field-planted seedlings from different stock types

Stock type	Years 1992	1993	1994–1999
1+0 container	91 b [a]	89	88
1+0 bareroot	97 ab	91	91
2+0 bareroot	98 ab	97	97
MP+1 (mini-plug transplant)	100 a	95	95

[a] In each column, means followed by different letters are significantly different by a Fishers Protected Least Significant Difference (LSD) Test, following an arcsin transformation of the percentage data.

At time of planting, 20 each of the 1+0 bareroot, 2+0 bareroot, and mini-plug seedlings were randomly selected for destructive sampling. Not enough container seedlings were available for these measurements. We cut each seedling at the cotyledon scar and weighed the shoots and roots after drying for 48 h at 70 °C (158 °F). Shoot-to-root ratios were also calculated.

We recorded initial height and diameter of each field-planted seedling and re-evaluated survival, total height, and basal diameter at the end of each of the first 5 growing seasons. Height was measured as the distance from the base of the seedling to the tip of the longest branch held vertical. Seedlings were remeasured 3 y later (1999), but had become so large that it was impossible to measure height in the previous manner, so height was measured as the distance to the tallest point of their natural configuration.

Annual precipitation at the SFREC averages just under 75 cm (29.5 in). During the 8-y interval of our study, the weather was slightly wetter than normal, with 5 y above average, including two of the first four, and three below.

All field data were analyzed using two-way analysis of variance for a randomized block design. The initial shoot and root dry weights and shoot-to-root ratios were analyzed by a one-way analysis of variance. Only when ANOVAs indicated that there were significant differences among stock types were multiple comparison tests (LSD) performed to determine which treatments were significantly different ($P < 0.05$). Survival data was transformed prior to analysis using an arcsin transformation.

Results and Discussion

Field survival of all stock types was high, averaging over 92% after 8 y (Table 1). The only significant difference in survival occurred the first year when container seedlings had lower survival than mini-plugs. No additional mortality occurred after the third growing season, suggesting that regardless of stock type, once seedlings survive the first couple of years, it is highly likely they will remain alive as long as they are adequately protected from damaging animals and provided sufficient weed control. High survival could not be attributed to unusually favorable weather conditions because 2 of the first 3 y had below average rainfall.

Average root weights of mini-plug transplants were almost double those of 2+0 bareroot seedlings, even though they were a year younger, and were almost triple those of 1+0 bareroot seedlings (Table 2). Qualitatively, mini-plug transplants also had more fibrous root systems. They also had significantly greater stem weights than 1+0 bareroot seedlings and significantly smaller shoot-to-root ratios than 2+0 bareroot seedlings.

The mini-plug transplants were significantly taller than either the container seedlings or 1+0 bareroot seedlings at time of planting and at the end of 1992, 1994, 1995, and 1996 (Table 3). Their basal diameters were also significantly greater at planting and in 1992, 1993, and 1994 than these other 2 stock types (Table 3). By 1999, however, mini-plugs were only significantly taller than container seedlings.

Field performance of mini-plug transplants and 2+0 bareroot seedlings was very similar throughout the study. Significant differences between both stock types were lacking for any of the 3 field variables in any year, except 1999, when 2+0 bareroot seedlings had larger basal diameters than mini-plug transplants. The 2+0 bareroot seedlings also had significantly greater height and diameter than either 1+0 bareroot or container seedlings in every year of the study (except 1995 when all stock types had similar diameters).

TABLE 2

Morphology of different stock types at time of planting

Stock type	Stem weight (g)	Root weight (g)	Shoot-to-root ratio
1+0 bareroot	1.4 a [a]	3.9 a	0.36 b
2+0 bareroot	3.8 b	5.3 a	0.68 a
MP+1 (mini-plug transplant)	4.6 b	10.4 b	0.43 b

[a] In each column, means followed by different letters are significantly different by a Fishers Protected Least Significant Difference (LSD) Test.

Since mini-plug transplants appeared superior to container and 1+0 bareroot seedlings, the question then becomes what are costs and benefits associated with various stock types and when might one be preferred over others? From strictly a cost standpoint, mini-plugs are more expensive to produce than the other 3 stock types, because production requires a container and bareroot facility as well as transplanting. The following are the relative sale prices per 100 seedlings for the 4 stock types in 1990:

1+0 bareroot — $50
2+0 bareroot — $65
1+0 container — $92
MP+1 (mini-plug transplant) — $111

However, mini-plug transplants can be grown in a single year, rather than 2 y required for 2+0 bareroot seedlings, and this shorter production time may be important. Mast production in blue oaks is notoriously inconsistent (Koenig and Knops 1995) and it is generally impossible to store acorns from species in the white oak group for more than a few months without a deterioration in quality (Bonner and Vozzo 1987). Acorns may simply be unavailable when needed for sowing. If a good mast year coincided with a requirement for seedlings 1 y later—say as a mitigation requirement for tree removal associated with development—then a 1-y production schedule may be essential. It would then be necessary to weigh costs versus the expected improved field performance of the mini-plug transplants as compared with the other two 1+0 stock types to decide which was preferable. Since 1990, the relative costs of 1+0 container seedlings have also increased in comparison to those for mini-plug transplants, so both stock types are now comparably priced. If time is not a constraint, however, our results suggest that compared to mini-plug transplants, 2+0 bareroot seedlings provide as good or better field performance with less cost.

Author Information

Doug McCreary
Program Manager
University of California's Integrated Hardwood Range Management Program
8279 Scott Forbes Road
Browns Valley, CA 95918
ddmccreary@ucdavis.edu

Laurie Lippitt
Nursery Manager
California Department of Forestry and Fire Protection
LA Moran Reforestation Center
PO Box 1590
Davis, CA 95617
laurie_lippitt@fire.ca.gov

Conclusions

Our results suggest that though it is possible to produce blue oak seedlings with large fibrous root systems using the mini-plug method, the advantages in terms of improved field performance are relatively minor. Although mini-plug transplants grew larger in the field after the first 3 y than either 1+0 bareroot or 1+0 container seedlings, by the eighth year, they were only significantly taller than container seedlings, and their diameters were similar. However, 2+0 bareroot seedlings had larger basal diameters, indicating field performance was just as good or better than mini-plug transplants. Because mini-plug transplants are more costly to produce than standard bareroot seedlings, they do not appear to be cost-effective. However, when large robust seedlings are needed in a single year, or acorn availability limits the length of the production cycle, mini-plug transplants may be desirable. They may also offer some limited advantages over 1+0 containers because they currently cost about the same and grow as well or better after outplanting.

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TABLE 3

Average seedling height (cm) and basal diameter (mm) for field-planted seedlings from different stock types

	Year													
	At planting		1992		1993		1994		1995		1996		1999	
Stock type	height	diameter	height	diameter	height	diameter	height	diameter	height	diameter	height	diameter	height	diameter
1+0 container	18 a[a]	2.9 a	28 a	5.6 a	54 ab	10.7 a	80 a	16.3 a	104 a	24.1	141 a	33.0 a	201 a	60.3 a
1+0 bareroot	23 b	4.2 b	29 a	6.1 a	52 a	10.1 a	75 a	15.9 a	104 a	23.4	146 a	32.6 a	211 ab	61.2 a
2+0 bareroot	33 c	5.0 c	39 b	6.8 b	65 c	12.3 b	93 b	18.7 b	128 b	27.0	172 b	37.8 b	227 c	69.7 b
MP+1 (mini-plug transplant)	33 c	5.4 c	38 b	12.6 b	64 bc	12.6 b	93 b	18.9 b	120 b	26.5	164 b	36.8 ab	219 bc	63.9 a

[a] In each column, means followed by different letters are significantly different by a Fishers Protected Least Significant Difference (LSD) Test.

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