Effectiveness of 'Tap-Root' Bags in Establishing Plantings of Oak (*Quercus lobata* Nee)

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16. Abstract

Oak trees (*Quercus lobata* Nee) were grown from acorns in a 2:1 (v/v) mix of Fir bark mulch and sand with major nutrients in a 0.5 m x 16 cm x 6 mil thick black polyethylene bag with four 2.5 cm drainage holes punched in the bottom. One year seedlings were planted in drilled holes of the same dimensions as the bag and the shoot enclosed in a 0.5 m tall tree shelter. Survival of seedlings at 3 sites (over 200 plants each) after 1 growing season (May-September 1993) ranged from 1 to 34%. Mortality was associated with rodents eating the roots and cambium layer at the base of the stem. Weed growth in the shelters was also observed. Two year seedlings (142 plants) were planted at one site that had 12% survival over the prior 1993 growing season. The root balls of the plants were fitted with a open bottomed 10 cm diameter root guard of 1.25 cm galvanized poultry netting that extended 0.5 m into the soil. The top of the guard was crimped on to the flange of an inverted 0.5 m tall Tubex™ shelter. No weed growth was observed extending from shelters with live seedlings. These plantings had a survival rate of 39% after one growing season (May-September 1994). Association of mortality (78% of deaths) with rodent damage was statistically significant. Damage was caused by rodents burrowing down the outside of the root guard and entering through the open bottom. Irrigation of the plantings at two week intervals (June-July 1994) did not affect survival. Use of closed bottom root guards (baskets) is recommended when planting in areas with rodents. The use of seedlings grown in long bags may remove the need for supplemental irrigation during establishment. Measurement of the breakdown of galvanized poultry netting is recommended for further study to see if the guard interferes with the root growth of maturing seedlings.

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DISCLAIMER

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DISCLOSURE

This research (Federal Study No. E93LA08) was conducted by the California Conservation Corps, Napa Satellite, Santa Clara Service District, under Interagency Agreement No. 53U071, at a total cost of $43,571.89.

IMPLEMENTATION

The findings of this report will be useful to landscape architects, botanists, biologists, contractors and the public who undertake to plant oak trees. Caltrans plants many oaks each year for environmental mitigation and aesthetic enhancement. Oaks are also planted on Caltrans roadsides by others through Adopt-A-Highway permits, the Transportation Enhancement Activities (TEA) program and the Environmental Enhancement and Mitigation (EEM) program. The information contained herein will serve as technical support to those efforts and as a stimulus for continued research and dialogue.

INTRODUCTION

California environmental mitigation requirements frequently require the planting and establishment of native plants. Native oaks show promise as routine landscape materials because these species require little water, are adapted to California's Mediterranean climate, are pest resistant, can be propagated easily from existing natural populations, and are available in a wide range of species (3,8,9). The primary disadvantage of oaks are that they are slow growing, though slow growth offers the maintenance advantage of minimal pruning and maintained tree vigor once the tree becomes full size. An unirrigated oak tree becomes a significant landscape element (a small pole-like 'tree') in about 15 years, a full size specimen in about 30 years (elm stage), and has a useful lifetime exceeding 6 centuries (3,10).

Irrigation water is not readily available in many areas. We investigated a method of establishing oak seedlings without any irrigation or with minimal supplemental irrigation. A successful method would aid in meeting environmental committments and conducting planting projects within existing irrigation limitations. Oak trees (*Quercus lobata* Nee) were grown in 'tap-root' bags (a plastic bag) and '1 gallon' plastic containers for one to two years. The one year old seedlings were planted at three locations with varying seasonal rainfall during March and April 1993 (Table 1: 18 to 76 cm). The survival of the plantings was measured in September and October 1993 and in July 1994. The survival of the plantings in one location was also compared to the survival of acorn plantings within the region planted in February 1993. Most of both seedling and acorn plantings (Table 3: 66-99%) did not survive, presumably due to severe rodent depredation. A subsequent planting, using two year seedlings, was installed in February 1994 and surveyed in October 1994 to test a more rigorous method of rodent exclusion. The method deployed was only partially successful, but did substantially increase survival in the rodent infested site from 1% to 39% (Table 3 versus Table 6).

MATERIALS AND METHODS

Propagation

Tap Root Bags

Quercus lobata acorns (20 kg) were collected in September-October 1991 from four locations: Hopland adjacent to University of California Agricultural Research Center (USGS Quad "Purdys Gardens": 39°00'30" N:123°5'00": 158 m), Dixon at the county fairgrounds ("Dixon": 38°26'30" N:121°49'00": 15 m), Stockton on the University of the Pacific Campus ("West Stockton": 37°59'00" N: 121°19'00": 3 m), and Napa northeast of the State Mental Hospital along Coombsville Road ("Mount George": 38°17'30" N: 122°14'00": 30 m) and stored without refrigeration at the California Conservation Corps Native Plant Nursery in Napa, California ("Napa": 38°16'30" N: 122°15'30": 27 m) until they were planted January 1992. Locations are approximate to the nearest 30 seconds.

Prior to planting, 200 acorns at a time were dumped into a bucket (20 l) of local tap water and, after 24 hours, fully submerged acorns were selected. The selected acorns were germinated in a shallow germination box (30 cm x 90 cm x 20 cm) in 20 cm deep layer of peat:vermiculite:perlite (1:1:1 by volume). The acorns were placed tip down about with the cap

2.5 cm below the soil surface. When a 5 to 50 mm root had emerged, the acorn was transferred to the nursery container. 400 germinated acorns from each seed source were planted 5 cm deep, horizontally, in a sterile planting mix of Fir (*Abies sp.*) mulch: sand (2:1 by volume with nutrients:4.3 kg/m^3 dolomite lime, 2.2 kg/m^3 single super phosphate, 1.1 kg/m^3 ferrous sulfate, 0.8 kg/m^3 potassium nitrate, 2.2 kg/m^3 sulfur coated urea). 375 acorns were planted in a 'tap-root' bag consisting of an 0.5 m deep, 16 cm diameter, 6 mil thick trash bag, end thermal welded shut (Gemini Enterprises, Mayworth, CA) with four 2.5 cm holes punched in the base. The remaining 75 acorns were planted in standard '1 gallon' black polyethylene pots (Pacific Pots, San Jose, CA). The containers were irrigated by overhead sprinklers as required for one year or two years.

4 inch Deepots™

Acorns (20 kg) were collected in September-October 1992 at the Coombsville road location and treated as above, except that the acorns were planted January 1993 in 10 cm deep ('4 inch') Deepots™ (Stenwe & Sons, Corvalis, OR) and grown at the Napa nursery as previously described prior to planting.

Research Plots

Research plots were installed in California near Lakeport at the Parkway overpass on Highway 29, near Dunnigan at the junction of Highway 505 and Interstate Highway 5 , and near Vernalis at the junction of Interstate Highway 5 and Highway 580. A plot could take up to 3 consecutive days to install with a crew of 8-10 California Conservation Corps corpsmembers. Table 1 summarizes site data.

Table 1. Site Description Summary

Site Name	**Date Installation Started**	**Longitude/ Latitude/ Elevation**	**Soil Type**	**Typical Annual Rainfall** ***Min/Max/Avg Temperature***
Lakeport Parkway/29 Quad: Lakeport	12 April 1993	39° 5' 00" N 122° 55" 30" 440 m	Manzanita Loam *with miscellaneous fill soils*	71-76 cm *Temperature data not available*
Dunnigan I-5/505 Quad: Zamora	#1: 5 March 1993 #2: 15 February 1994	38° 51' 00" N 121° 56' 30" 17 m	Rincon silty clay loam	38-41 cm 2/34/15.6 °C [1]
Vernalis I-5/580 Quad: Solyo	18 March 1993	37° 37' 00" N 121° 20' 00" 79 m	Zacharias gravelly clay loam	18- 20 cm 1/32/14.4 °C [2]

Average yearly rainfall values are from "Lines of Average Yearly Precipitation in the Central Valley, North Half" California Department of Water Resources April 1966. Soil types were determined from Soil Conservation Service soil maps.

[1] California Irrigation Management Information System (CIMIS) sensor station #27(Zamora) 38°48'30"N, 121°54'29" 1 March 1993 to 31 May 1995

[2] CIMIS sensor station #71 (Modesto) 37°38'10"N 121°11'10" 1 March 1993 to 31 May 1995

Plant Installation

A 1.25 x 1.25 m area of soil surface was cleared of weeds with a McCleod fire rake (Forestry Suppliers, Jackson, MS). With the exception of one treatment, which used a 30 cm ('12 inch') diameter bit, all plantings consisted of drilling a planting hole 60 cm deep with a gasoline powered auger (Orchard Hardware Supply, Stockton, CA: Tanaka TEA-500) attached to a 10 cm ('4 inch') diameter bit. The planting container was removed prior to planting.

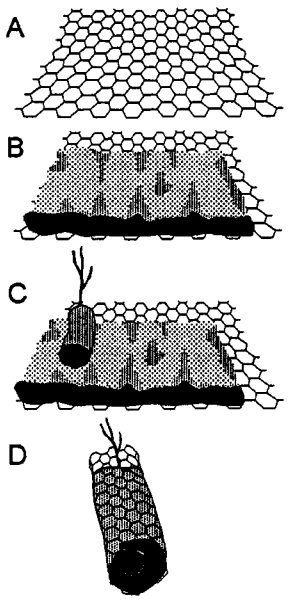

Figure 1. **A:** 40 cm wide by 60 cm deep section of poultry netting (1.25 cm net, 1.2 mm diam. "22 gauge") is laid flat. **B:** Native soil is formed into a pad on the netting with 10 cm of netting extending above the upper end. **C:** The seedling root ball is placed on top of the soil with the top of the root ball aligned with the upper edge of the pad. **D:** The guard/soil is rolled around the root ball to make a solid cylinder.

If a rodent root guard was used, the guard was installed as shown in Figure 1. The protected root ball was inserted into the drilled hole. At the time of planting, the clay loam was wet from rains and did not fall from the netting during insertion. When necessary, original soil was placed in the bottom of the hole, underneath the root ball, to place the plant root crown at the original soil surface elevation. Original soil was then tamped in place with a wooden stake (approximately 2.5 cm x 0.6 cm x 60.0 cm) around the outside circumference of the root ball until the hole was filled to original soil surface elevation. Care was taken to prevent air pockets from being created during this backfill operation. The plant was then watered with about 4 liters of tap water. Additional original soil was added to fill any depressions created by settling of soil due to watering.

Prior to planting a 1.25 x 1.25 m mat of landscape cloth (Remay Corp., Old Hickory, TN) with a 15 cm 'X' cut along the diagonals of the square was prepared and placed in the square area of cleared soil. The plant shoot was inserted through the center opening. The mat was aligned to sit within the scraped area during installation and held in place at each corner by jute wire staple of ungalvanized steel wire (2.5 mm diam. '10 gauge', approximately 15 cm long with 2.5 cm wide spacing between legs). A plastic tube tree shelter or wire netting guard was then placed around the seedling and staked into place.

Two sets of plantings were installed using the same set of acorns. One (Study 1 and 2) with one-year seedlings and a second (Study 3), a year later, with two-year seedlings.

Treatments and Evaluation of Seedling Survival

Study 1: (one-year tap root bag grown seedlings)

An example plot layout is shown in Figure 2. Each experimental unit consisted of 5 seedlings planted 3 m apart in an 'X' pattern. 5 replicates of each unit were installed at the Vernalis and Dunnigan sites. 3 replicates were installed at the Lakeport site because there was not enough room for 5 replicates. Separate plots were used for each experiment: acorn source

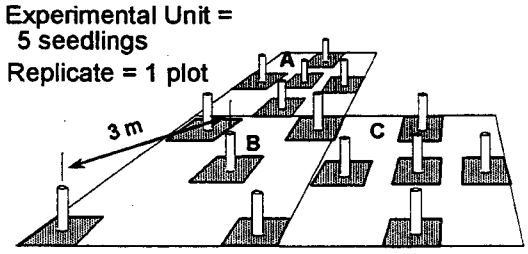

Figure 2. A,B,C represent separate treatments. Each experiment has 5 plots, each laid out similarly to above.

and growth with or without a weed control mat (Plot #1: 4 sources and mat; 4 + 1 treatments), diameter of planting hole (Plot #2: 30 cm versus 10 cm; 2 treatments), tree shelter type (Plot #3: Tubex, Blue-X, Chickenwire; 3 treatments; Table 2), and planting container size (Plot #4: '1 gallon' container versus tap-root bag; 2 treatments). Plots were installed from February 1993 to April 1993 (Table 1). Survival of the seedlings was determined in June 1993, October 1993, and July 1994. A plant was scored as surviving by observing at least one green leaf attached to the stem.

Table 2. Tree Shelters

Shelter	**Tubex™**	**Blue-X™**	**Chickenwire**
Dimensions	8-11 cm diam. x 60 cm high	5 cm x 10 cm ellipse x 380 cm high	15 cm diam. x 60 cm high; 2.5 cm mesh; 1.25 mm diam. wire '20 gauge'
Source	Treessentials St. Paul MN	All Seasons Nursery Elk Grove, CA	Lumberjack Sacramento, CA

Study 2: (acorn plantings)

Acorn plantings approximately one year old were inspected to determine the relative survival of acorns planted in Blue-X™ and Tubex™ shelters. During installation of the plantings (Figure 3), a 70 cm diameter circle was cleared of weeds with a fire rake and the planting installed in the circle's center. Plantings were randomly spaced 7.5 m apart. The acorns had been planted two inches deep on a soil bed created by augering a 60 cm deep by 10 cm wide hole, placing a fertilizer tablet in the bottom of the hole (Best-tabs Brand, 21 gm, 20-10-5 NPK, J.R. Simplot Company, Lathrop, CA) and backfilling the hole with native soil. Sterile commercial potting soil (250 ml:Greenall Brand, EB Stone & Sons Inc., Suisun, CA) was used to cover the acorns. A 8 cm deep x 30 cm diam. layer of mulch derived from chipping of local tree trimming waste was placed around the shelter to retard weed growth. Ten sites were surveyed. Plants were scored as surviving if they had at least one green leaf attached to a stem.

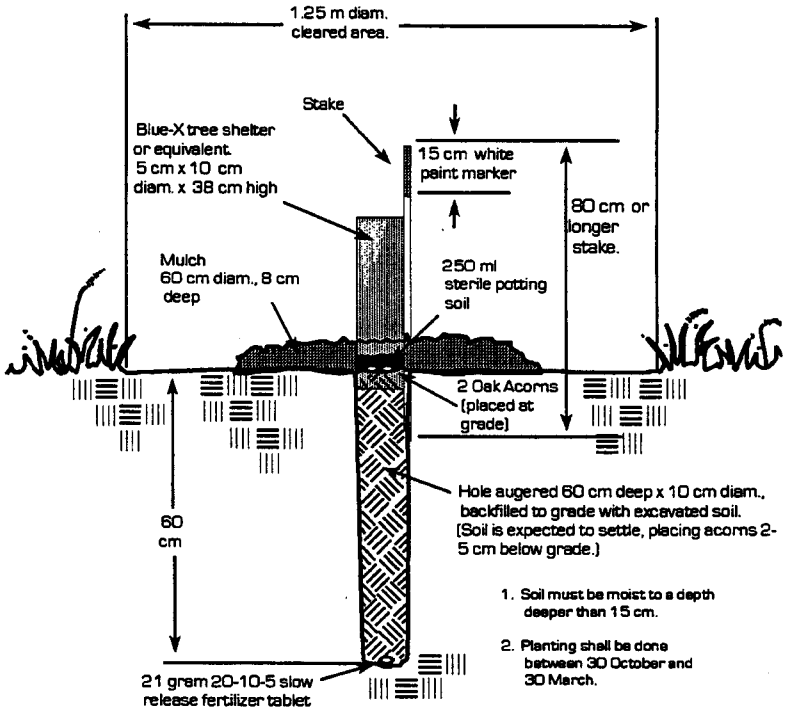

Figure 3. Acorn planting specification. *Source: California Department of Transportation*

Study 3: (two-year tap root bag grown seedlings and one-year Deepot™ grown seedlings)

An example plot layout is shown in Figure 4. Each experimental unit

consisted of five seedlings planted as mentioned in "Planting Method" with Tubex™ tree shelters in a staggered row 2.5 m apart. Treatments were installed as adjacent rows. Five replicates were installed at the Dunnigan site. Two sets of 5 plots, each plot containing a set of replicates, were set-up, one with tap-root bags and the second with 10 cm Deepots™.

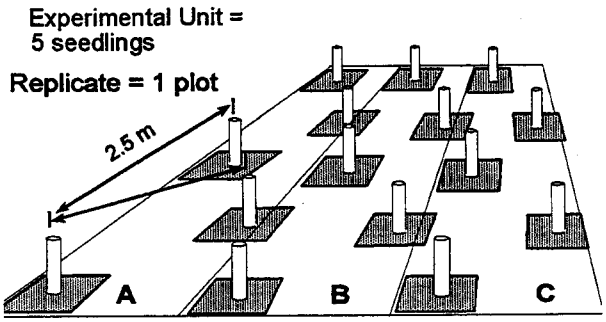

Figure 4. A,B,C represent separate treatments. Each experiment has 5 plots, each laid out similarly to above.

The tap-root bag plots had five treatments: two treatments with no additional water besides the initial watering immediately following planting, one treatment with a root guard and one without; and three treatments with additional irrigation; 1, 2, 3 waterings; each two weeks apart. The watering regime was started 17 June 1994 and concluded on 22 July 1994. Water was applied using a hand-operated bilge pump attached to a 1,120 l polypropylene tank (Figure 5) hauled by a pick-up truck with a 2 ton cargo capacity (General Motors Corporation, SL Sierra). The tank was braced with wood forms to prevent sliding during transit. Additional irrigation was supplied as approximately 8 l.

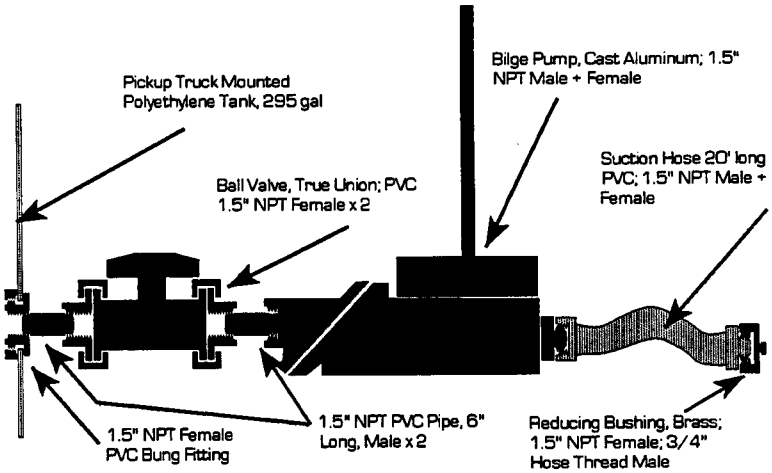

Figure 5. Schematic of water tank hand pump, shut off valve, and hose hook-up. (Tank and fittings, American Tank Co., Windsor CA; Bilge pump, Forestry Suppliers, Jackson, MS; Suction hose, Northern Hydraulics, Burnsville, MN)

Seedlings were scored as surviving by having either at least one green leaf attached to a stem, or by having green cambium beneath a section of bark located 8 cm below the shoot tip and at least one live bud above this point. Dead plants (plants not scored as surviving) were scored as rodent damaged if the plant separated from the ground after being firmly pulled upward by grasping the trunk and if the plant had gnaw marks at the point of separation.

The Deepot™ plots had five treatments set-up identically to the tap-root bag trial with an additional 6th treatment where a 1 l container of DriWater™ was installed. This treatment received no additional irrigation besides the irrigation (1 l) immediately following installation. The container was installed by pulling up the weed cloth and digging a 30 cm long by 10 cm wide trench extending radially outward from the north face of the planting with the trench floor at a 45 degree decline, the low end adjacent to the root ball and the high end at grade level. Prior to installation the bottom of the DriWater™ container was cut along three sides, the bottom folded back, and 5 ml of Osmocote™ 18-6-12 NPK beads (Grace Sierra, Milpitas, CA) were embedded in the surface of the gel to promote degradation and water release. The open end was placed against the root ball. After installation, the highest edge of the container (a rectangular prism 'milk carton') was coated with glue ('UHU stic: Color U75C 21gms'

FarberCastell, Lewisburg, TN) and sprinkled with cayenne pepper ('Spice Islands 57 gms' Burns Philip Food, Inc San Francisco, CA) to discourage rodents from gnawing the container to obtain moisture. The container was buried and the excavated soil and weed cloth replaced.

Survival was determined 10 October 1994. Seedlings were scored as surviving if they had at least one green leaf attached to the stem.

RESULTS

Study 1: (one-year tap root bag grown seedlings)

All three sites (Lakeport, Dunnigan, and Vernalis) showed substantial mortality (Table 3) with the Lakeport site showing the highest survival rate. There were no significant differences between treatments within experimental plots as determined by computation of the F statistic ($P<0.10$).

Table 3. Percent of Plants Surviving from Original Planting

Location	Seedlings Planted	Spring 1993	Fall 1993	Fall 1994	Typical Annual Rainfall
Lakeport	210	97.3%	29.0%	34.3%	71-76 cm
Dunnigan	345	91.3	12.2	1.4	38-41
Vernalis	300	57.3	1.3	1	18- 20

Study 2: (acorn plantings)

The treatments (Table 4) using Tubex™ shelters showed a 7 month survival rate of 36% and treatments using Blue-X™ shelters showed a 7 month survival rate of 21%. A two-tailed t-test using paired replicate means showed that the treatment means are significantly different ($P<0.05$).

Table 4. Survival of 1,541 acorn plantings at 9 highway interchanges 7 months after planting.

Plot #	# Planted	Date Planted	Date Surveyed	Plants Located	*Tubex™* # Live Seedling	*Tubex™* # No Live Seedling	*Tubex™* Percent Survival*	*Blue-X™* # Live Seedling	*Blue-X™* # No Live Seedling	*Blue-X™* Percent Survival*
6	60	04-Feb-93	28-Oct-93	39	3	12	20.00%	1	18	5.26%
7	200	05-Feb-93	28-Oct-93	252	17	105	13.93	9	121	6.92
8	140	18-Feb-93	25-Oct-93	137	25	41	37.88	14	47	22.95
9	490	26-Feb-93	25-Oct-93	457	87	128	40.47	37	208	15.10
10	294	19-Mar-93	24-Oct-93	299	45	31	59.21	75	148	33.63
16	185	12-Feb-93	28-Oct-93	138	26	26	50.00	20	66	23.26
17	56	10-Feb-93	28-Oct-93	56	3	21	12.50	1	31	3.13
19	80	10-Feb-93	25-Oct-93	75	13	21	38.24	7	34	17.07
20	92	08-Feb-93	28-Oct-93	88	11	10	52.38	42	25	62.69
			TOTAL	1541		Mean	36.07%		Mean	21.11%
						Std Dev	17.05%		Std Dev	18.44%

* % Survival = living seedlings/ total plantings surveyed.

Tracking of the survival of 229 acorn plantings at the Dunnigan site (Table 5) installed during March 1993 showed that 32% had produced living seedlings in June 1993. The plantings were surveyed again after the dry season in October 1993. Pooling the observations for both shelters, 44% of the seedlings in spring survived or 14.5% of the original plantings. The survival rates of plantings using Blue-X™ shelters were, at most, 2% below the rates observed for plantings using Tubex™ shelters.

Table 5. Seedlings observed at acorn plantings at the Dunnigan Site. All shelters found were counted.

	Seedlings Observed					
	Tubex™			*Blue-X™*		
Survey Date	**Dead**	**Living**	**% Living**	**Dead**	**Living**	**% Living**
17 June 1993	72	36	33	83	38	31
7 October 1993	19	15	44	17	13	43

Study 3: (two-year tap root bag grown seedlings and one-year Deepot™ grown seedlings)

Scoring of the plantings using the tap root bag showed that 39% were scored as living, 47% as dead and rodent damaged, and 13% as dead with no observed rodent damage (Table 6). The observed difference in the trials between dead with rodent damage and dead without rodent damage was significant ($P<0.05$) as determined by a one-tailed t-test. Excavation of five randomly selected rodent damaged seedlings showed that the rodent had burrowed downward along the outside of the guard and entered through the open bottom. Fraying of the weed cloth around the hole's opening showed that the rodent had made multiple visits. In no case was entry observed to occur through the poultry netting.

Table 6. Observed status of tap-root bag plantings on 12 Oct 1994. Plots were planted 15 Feb 1994 at the Dunnigan site. Rows marked with the same letter are not statistically different (P<0.05).

	Plants Surviving		
Observation	**Total**	**%**	
Dead, no rodent damage	19	13%	a
Dead, rodent damage	67	47%	ab
Live	56	39%	b

The trial involving DriWater™ showed no significant differences between trials (P<0.10) as determined by computation of the F statistic. Almost all of the plantings died regardless of treatment (Table 7).

Table 7. Observed status of Deepot™ plantings on 12 Oct 1994. Plots were planted on 15 Oct 1994 at the Dunnigan site. Waterings were 4 l, two weeks apart and started 17 June 1994 and ending 22 July 1994.

	Replicate (plot)		*Plants Surviving*		
Treatment	**1**	**2**	**3**	**4**	**5**
Control	0	2	0	0	3
1 Quart DriWater	0	1	0	0	2
One extra watering	0	0	0	0	2
Two extra waterings	0	0	0	0	1
Three extra waterings	0	1	0	3	1

% seedlings surviving = 13 living/ 125 planted = 10%

DISCUSSION

Tap Root Bags

Two year seedlings grown in 60 cm deep tap root bags (Study 3) showed greater success in surviving one dry season (39%,Table 6) when compared to acorn plantings (Study 2, 15/72=14.5%, Table 5) or Deepot™ plantings (Study 3, 10%, Table 7) at the same site. Irrigation did not improve survival [Results: Study 3 (two year tap root bag grown seedlings)]. Some investigators find irrigation to promote the growth of seedlings from acorns (2,6) .

Rodents often damage oak plantings (1,4,12). Rodent depredation was severe (47%, Table 6) despite the installation of rodent root guards. The rodent guards were only partially effective because rodents could enter through the open bottom and damage the seedling's root system by eating parts of it. The disturbed soil around the planting may attract the rodents, which can burrow easily through the soil and underneath the guard. Extensive populations of field mice were observed at the site. No pocket gopher mounds were evident.

The tap root bag may support greater survival because the 60 cm deep by 10 cm wide root ball (4.7 l) can serve as a water and nutrient reservoir. Acorn plantings or Deepot™ plantings lack a similar reservoir. Because of a delay in contracting, the first tap root bag experiment (Study 1) was planted late, April 1993, in the typical November through May wet season. This delay could potentially account for the observed low seedling survival (Table 1 and Table 3) by denying the seedlings a sufficient growing season. The seedlings are dormant from December through May, so planting after November would confer little benefit. In addition, 1993 was a particularly wet year with rains until the end of June, providing ample water. Also, a subsequent study (Study 3) showed that rodent depredation, rather than lack of water, was strongly associated with seedling mortality (Table 6) at the Dunnigan site.

Acorn Plantings

The Tubex™ tree shelter was more effective (36%, Table 4) compared to the Blue-X™ (21%, Table 4), shelter when 9 highway interchange sites were surveyed. The two shelters performed similarly at the Dunnigan site. Microclimate factors (e.g. heat, humidity) may play a role in determining how well the seedlings perform in each type of shelter. The design of the Blue-X™ shelter has been altered subsequent to the experiment to reduce interior heating, so these results do not necessarily apply to the commercially available version. Several acorn plantings showed settling, which placed the seedling root crown below the surrounding soil surface. The resulting depression collected water, which could promote crown rot. Reducing the hole depth to 30 cm to inhibit settling and replacing potting soil with sand would provide a dryer microclimate around the seedling's crown.

DriWater™/ Deepots™

Survival of Deepot™ plantings was very low (10%, Table 7). The seedling root ball was very small compared to the tap root bag grown seedlings and probably dried out quickly, even with the additional irrigation. DriWater™ or the biweekly supplemental irrigation did not confer any benefit. Because almost all plantings died, the experiment was unable to provide a

measurement of DriWater's™ efficacy. The installation of more units per plant and installation at time of planting should be investigated.

Maintenance

The Tubex™ shelters were significantly more visible in tall grass than the Blue-X or chicken wire shelters. Shelters with seedlings also had the noticeable feature of a green shoot extending from top against a background of brown vegetation. Acorn seedlings are not visible for at least the first year and the shelters were frequently mowed over by maintenance crews. Visibility is important because highway interchanges are frequently mowed to inhibit fire. Mowing is typically done after the grass or other vegetation has grown to its full height, so mowing crews must be able to clearly see the shelters so that they can avoid them. Also, shelters with protruding green shoots are probably more aesthetically pleasing than the shelters alone (with smaller obscured seedlings).

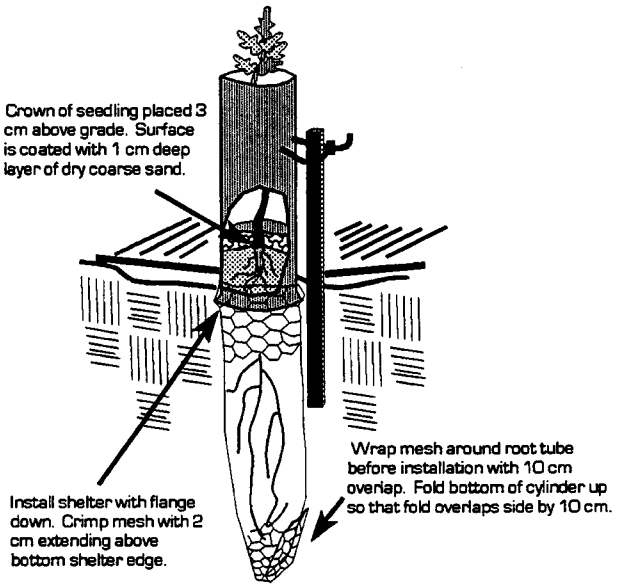

Figure 6. Recommended revisions to planting specification for tap-root bags to reduce rodent damage and inhibit root crown rot.

Fiber mesh covers for the top of the shelters is frequently prescribed to prevent birds from becoming trapped in the shelters (Tubex™ sales literature). In these studies, a mesh cover was not installed because of the potential for the mesh to interfere with shoot elongation. Dead birds were never observed in any shelter. The seedlings usually occupy most of the shelter and may serve to deter birds from entering the structure.

Annual grasses are frequently found to compete with oaks for soil moisture and mulching or otherwise preventing weed growth has been shown to usually promote seedling gowth (1,2,4,7,6,5,13). The weed cloth effectively prevented weed growth, but was destroyed along with the shelters when exposed to grass fires. The shelters frequently promoted weed growth in the second year with the shelter appearing as a "tuft" of weeds extending 60 to 90 cm above the surrounding vegetation. Shading of the shelter interior and deposition of leaf litter inside the shelter by larger seedlings should inhibit weed growth.

RECOMMENDATIONS

Based on the above observations, the use of two-year oak seedlings grown in a tap root bag or equivalent container is recommended over acorn plantings or Deepot™ plantings. Tree shelters and closed bottom root rodent guards (baskets) are necessary where rodent colonies exist. An inverted Tubex™ shelter (Figure 6), with a 1.25 cm poultry netting root guard is suggested. Data indicate that irrigation is not required in areas which receive 38 cm or more of average annual rainfall. To aid in maintenance, group plantings and plant more densely than ultimately required to allow for mortality and to encourage build-up of leaf litter and shade for weed control. If this approach were adopted, the planting would need to be thinned 5 to 10 years after installation to reduce inter-sapling competition and therefore allow the remaining

saplings to grow larger faster. Placing mulch on top of the landscape cloth would prevent shredding of the cloth by the persistent winds that are often present at highway planting sites. A marker stake extending at least 1 m above the soil surface should be placed adjacent to the planting to alert mowing crews to the planting's location. This stake should not be the same as the planting stake. Any stake touching and extending above the shelter can serve as a 'ladder' for pests to gain access to the seedling (as indicated by the presence of dead lizards in shelters secured with tall stakes). Paint colors other than white will bleach out in the sun. The estimated cost of planting 25 plants in a 25 m^2 area is about $23.00 per plant (1995 dollars), assuming 50% mortality (Figure 7, Table 8).

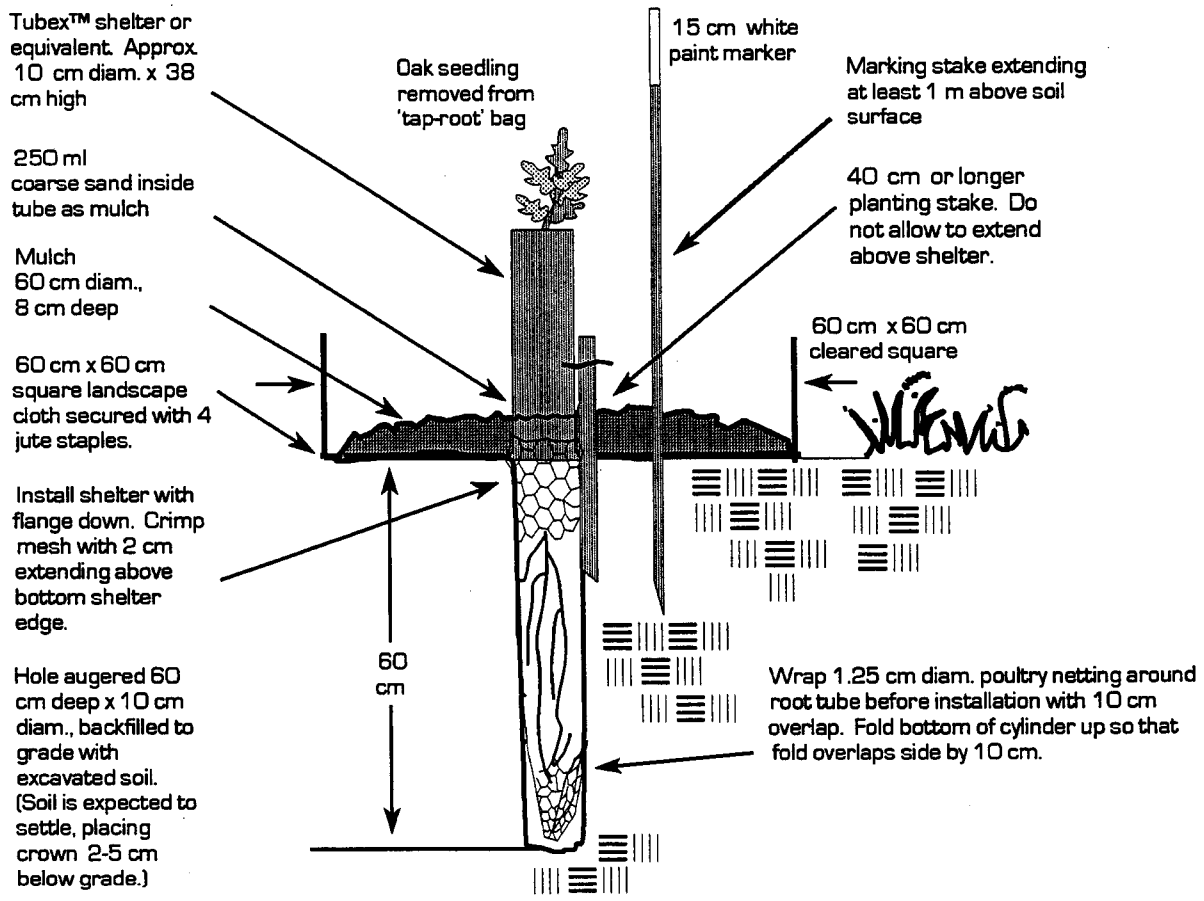

Figure 7. Recommended planting specification for seedlings grown in 'Tap-Root' Bags.

The effectiveness of one-year seedlings and supplemental fertilization in promoting seedling survival should be investigated. The root guard should disintegrate before it can girdle the tree's growing root system. If possible, galvanized root baskets versus ungalvanized should be used, since galvanized netting is readily available at local construction and farm supply stores. Anecdotal evidence shows that such guards have a lifetime of 3 to 5 years in irrigated orchards.

Table 8. Estimated cost of planting a 25 m^2 area, planting on 4 m centers. Thinning and shipping costs not included.

Description	Market Unit	Cost/ Market Unit	Cost/ Unit	Quantity	Extended Cost
Oak Seedlings in 'Tap-root' bags	each	$3.00 each	$3.00 each	25	$75.00
Tubex Tree Shelter with stake	case of 20	$28.00 case	$1.90 each	25	$47.50
Poultry Mesh (0.5 inch, 22 guage)	roll: 24 inches x 100 feet	$35.00 roll	$0.38 each	25	$9.50
Jute Staples	box of 50	$4.00 box	$0.08 each	100	$8.00
Landscape Cloth	roll: 4 feet x 300 feet	$95.75 roll	$0.32 linear foot	25 linear feet	$8.00
Mulch	100 cubic yards	$1,100 delivered	$11.00 cubic yard	0.5	$5.50
Course Sand	bag: 30 pounds	$14.50 bag	$0.25 liter	6.25 liters	$1.56
Marker Stakes with Paint	each	$0.35 each	$0.35 each	25	$8.75
CCC 10 person crew	1 day	$940 day	$134.00 hour	0.75 hour	$100.50
Subtotal					$264.31
10% Overhead					$26.43
Total					$290.74
Cost per final plant (50% survival)					**$23.26**

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ADDENDUM

A survey of the plantings of two year seedlings (Study #3) at the Dunnigan site on 28 September 1995 recorded 58 living plants at the end of the 1995 growing season (May-September). This value represents 104% of the plants observed living the end of the 1994 growing season. Therefore, no net mortality was observed after the first growing season in the second year of the planting.