Container Hybrid Pines Survive on a Harsh Dam Site

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The scar left after the construction of Trinity Dam in northern California is an extremely harsh site. It was successfully revegetated by planting and fertilizing containerized seedlings of a knobcone x Monterey pine hybrid (Pinus attenuata x Pinus radiata). Fertilization at the time of planting increased the growth of seedlings, but also made them more susceptible to injury from deer and late-season frost. Tree Planters' Notes 41(1):8-14; 1990.

Trinity Dam, which regulates the flow and stores surplus water of the Trinity River in northern California, is an earthfill structure 538 feet high with a crest length of 2,450 feet. The dam forms Clair Engle Lake, which has a storage capacity of 2,448,000 acre-feet. The dam was constructed of earthen material taken from 75 acres of mountainside immediately downstream of its location. The use of this material was convenient and also reduced the hazard to the power plant and spillway from a potential slide area.

However, the removal of all topsoil from the site left a visual scar that contrasts dramatically with the adjacent undisturbed forest (fig. 1). Unfortunately, since completion of the dam in 1962 until now, virtually no natural vegetation has become established in the disturbed area. Since 1968 the USDI Bureau of Reclamation has tried to revegetate this slope with different tree, shrub, and grass species. To establish vegetation, the bureau has tried hydroseeding and planting, along with mulching and irrigating. It found a knobcone x Monterey pine hybrid (*Pinus attenuata* Lemm. x *Pinus radiata* D. Don) to be the most promising species. However, when several thousand seedlings of this hybrid were planted, often only a few hundred seedlings survived until the end of the first growing season.

Much of the scar was devoid of vegetation even after being planted two or three times. In 1983, the size of future plantings was limited until methodology could be developed to improve survival and growth rates of knobcone x Monterey pine seedlings.

This paper describes the results of a joint study between the USDA Forest Service and the USDI Bureau of Reclamation to determine the effects of stock type, fertilizer, and planting season on the survival and growth of knobcone x Monterey pine seedlings at Trinity Dam.

Materials and Methods

Site. The scar at Trinity Dam is an extremely harsh site. Its aspect is west; slopes are 40 to 60%. Because all of the top soil was removed, what remains is skeletal material. Generally, only the C horizon is present. The surface material is extremely rocky; only limited amounts of fine particles are present to hold moisture and provide nutrients. Precipitation averages about 35 inches annually, and only about 10% of this falls between April and September. The availability of soil moisture for plant growth at the site is further diminished because of an extensive subsurface drainage system installed in 1968 to reduce the possibility of slope slippage. Maximum temperatures during summer are often above 100 °F; minimum temperatures during winter are often below 30 °F. Late frosts, such as one that occurred in April 1986, may injure flushing terminals of seedlings.

Seedlings. Bareroot and containerized knobcone x Monterey pine seedlings were used in this study. Both stock types were from the same seed source. Bareroot seedlings were grown at the Forest Service nursery at Placerville, CA, using methods worked out while producing 10 earlier crops. Container seedlings were grown at the Forest Service Tree Improvement Nursery at Chico, CA. This was the first attempt to grow knobcone x Monterey pine seedlings in the Leach super cells (9-cubic-inch single cell container). Seedlings of both stock types were 1 year old when planted. At the time of planting, the stems and foliage of bareroot and container seedlings were similar. Seedlings of both stock types were about 10 inches tall with a 0.2-inch basal diameter.

The root systems of the two stock types were very different. The roots of container seedlings were moist because the rooting medium was moist, and they had many white root tips and mycorrhizal roots. As with previous crops, the bareroot seedling roots were dry (little, if any moist packing material was placed in the packing bag) and had few white root tips or mycorrhizal roots. Records indicate that lifting windows and handling and storage methods were standard for seedlings of both stock types.

The potential of bareroot and container seedlings to develop buds and roots was determined by potting 30 seedlings of each stock type and placing them in a greenhouse. Air and soil temperatures and soil moisture were maintained at levels for rapid bud and root development. Thirty days after potting, the rooting medium of peat moss and vermiculite was washed from the roots. Root development was assessed by counting

Figure 1—*Trinity Dam and power house, and the scar left after their construction in 1962, as photographed in fall 1986.*

the number of new roots longer than 0.4 inches and measuring the longest root. Buds were assessed as being dormant, elongating, or flushing.

Experimental layout. The experimental layout in the field was a randomized block design with subsampling. Each of the 4 blocks was about 100 by 120 feet and contained 15 rows of 12 seedlings each. The rows ran across the contours. Spacing was about 8 feet within and between rows. Five of the 15 rows were randomly assigned one of three treatments: (1) fall-planted container seedlings, (2) spring-planted container seedlings, or (3) spring-planted bareroot seedlings. Therefore, each block contained 120 container seedlings and 60 bareroot seedlings. Three of the 5 rows of each treatment were fertilized with about 60 g of 16:20:0 13S granular fertilizer.

Planting and fertilizing. Seedlings were planted in 10- to 12-inch deep holes made with a 4-inch power auger. Only about 1% of the holes could be made without using a pry to help break or displace rocks. Seedlings were removed from the container or planting bag and immediately placed in the hole. Each worker planted both stock types. After the seedlings were planted, a second hole 6 inches deep was made about 3 inches away from seedlings selected to be fertilized. Fertilizer was poured into the second hole and then covered with soil. Planting and fertilizing were done by a forestry conservation crew from the Crystal Creek Correctional Facility.

The fall planting of container seedlings was done in October 1983. The spring planting of bareroot and container seedlings was done in February 1984. Rain ample enough for high seedling survival and growth rates fell before and after both plantings and was also ample enough to cause movement of fertilizer toward and away from the seedlings.

Data collection and analyses. All seedlings were examined at the time of planting and also after the first, second, and third growing seasons to determine stem vigor, height and basal diameter. A seedling was rated as having high vigor if a terminal was present and healthy, and a full complement of healthy needles was present. Data on stem vigor, height, and diameter were subjected to analysis of variance. Statistically significant differences between treatment means were determined by using Tukey's least significant difference (0.05 level) test.

Results and Discussion

Greenhouse testing of growth potential. Survival and growth of seedlings in the field depend on the outcome of an interaction between the quality of stock planted and its environment (2). High-quality stock will initiate shoot and root growth soon after planting. A strong correlation has been found between early bud burst and survival of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) seedlings (4). Because seedlings that initiate bud growth early also initiate root growth early, the correlation between early bud burst and survival probably reflects a correlation between early root growth and survival. The relationship between root growth potential and seedling survival has been demonstrated for a number of conifer species (1, 3, 5-8). Rapid root growth is especially critical on harsh sites like the scar at Trinity Dam, where soil moisture and nutrients are primary limiting factors.

Differences in bud and root development of knobcone x Monterey pine bareroot and container seedlings in the greenhouse were observed. The terminal buds on 14% of the bareroot seedlings were still dormant after 30 days in the greenhouse, 16% were elongating, and 70% were flushing. Terminal buds on all the containerized seedlings were flushing. Differences in root development were correlated

Table 1—*Percent of knobcone × Monterey pine seedlings that developed different numbers of roots and average length of the longest new root developed after 28 days of growing in a greenhouse*

Stock type	Seedlings with new roots (%) 0	1–5 roots	6–15 roots	16–30 roots	>30 roots	Average length of longest roots (in)
Bareroot	8	19	43	30	0	8.0
Container	0	0	46	54	0	15.5

with differences noted in bud development. Bareroot seedlings that did not break bud generally produced few, if any, new roots. For both stock types, seedlings that broke bud early generally developed more and longer roots than seedlings that broke bud later.

As bud development varied by stock type, so did root development. The number of new roots produced and the average length of the longest root varied by stock type (table 1). Seventy-three percent of the bareroot seedlings developed 6 or more new roots, each longer than 0.4 inches, while 100% of the container seedlings did. The average lengths of the longest roots developed on the bareroot and container seedlings were 8.0 inches and 15.5 inches, respectively.

If the positive correlation between root development under controlled conditions and seedling survival in the field that was identified for other species holds for knobcone x Monterey pine seedlings, the container seedlings should have a higher survival rate than bareroot seedlings. On this harsh site, survival potential of the 27% of the bareroot seedlings that developed 5 or fewer new roots longer than 0.4 inches is probably very low. All the container seedlings developed 6 or more new roots.

The relatively simple operation of potting seedlings and then examining bud and root development after 30 days provided valuable information. Besides indicating variation in seedling quality within and between stock types, potting tests may indicate where problems exist in the reforestation process. If potting results indicate that survival and growth potential are high, yet survival and growth in the field are low, the problem(s) probably occurred in the field. However, if the potting results indicate that survival and growth potential are low, then the problem probably occurred before the seedlings reached the field. Knowing where a problem occurred increases the probability of solving or avoiding it.

Outplanting trials. Survival of seedlings varied significantly by stock type (table 2). By the end of the first growing season, only 46% of the unfertilized bareroot seedlings survived in comparison to 82% of the container seedlings. Survival results from the field planting probably reflect the results from the potting tests. The seedlings that died apparently did not develop sufficient new roots to sustain growth during the long dry summer. Probably all of the seedlings in the 5-or-fewer-new-roots category and about half of those in the 6-to-15-new-roots category died after outplanting. If that is true, then seedlings on harsh sites such as the Trinity Dam scar should develop at least 10 new roots during the first month. No more bareroot seedlings died after the first growing season. By the end of the third growing season, survival of container seedlings decreased to 74%, which was still significantly higher than the 46% for bareroot seedlings (table 2).

Surviving bareroot and container seedlings grew at similar rates (table 2). Seedlings of both stock types were similar in size when planted; they were also similar in size after three growing seasons. The unfertilized seedlings did not thrive, as indicated by the low percentage of seedlings of each stock type that had high vigor.

Table 2—*Survival, high vigor, stem height, and diameter of fertilized (+) and unfertilized (0) bareroot (BR) and containerized (Cont.) knobcone × Monterey pine seedlings planted during the spring at Trinity Dam, CA*

Stock type	Fertilizer	Survival (%)	High vigor (%)	Height: Total (in)	Height: Increment* (%)	Diameter: Total (in)	Diameter: Increment* (%)
First growing season							
BR	0	46 a	55 ab	11.3 a	9	0.23 b	41
BR	+	32 a	61 b	11.6 a	13	0.25 b	56
Cont.	0	82 b	29 a	11.3 a	15	0.18 a	21
Cont.	+	56 ab	69 b	13.0 a	32	0.25 b	68
		(33)	(26)	(2.8)		(0.06)	
Second growing season							
BR	0	46 a	64 ab	15.7 a	39	0.32 ab	40
BR	+	32 a	83 c	17.2 ab	35	0.43 b	70
Cont.	0	75 b	52 a	15.0 a	32	0.29 a	59
Cont.	+	55 ab	74 bc	20.0 b	54	0.46 b	84
		(26)	(18)	(4.3)		(0.11)	
Third growing season							
BR	0	46 a	69 a	19.8 a	26	0.46 ab	44
BR	+	32 a	67 a	23.4 ab	36	0.63 bc	47
Cont.	0	74 b	61 a	19.6 a	31	0.43 a	49
Cont.	+	55 ab	86 b	26.6 b	33	0.71 c	53
		(27)	(16)	(6.6)		(0.19)	

*Percent increase over previous measurement.

Values within the same growing season that are followed by the same letter do not differ statistically at the 0.05 level. Values in parentheses denote the 5% Tukey least significant differences.

Outplanting fertilization trials. For seedlings of both stock types, survival was higher for unfertilized seedlings than for fertilized seedlings (table 2). This may have resulted from fertilizer burn of the root system. Even though the quick-release fertilizer was placed in a hole several inches from the seedling roots, apparently because of the rockiness of the soil and the heavy rains that followed planting and fertilizing, sufficient fertilizer came into contact with the seedling roots to cause injury. Bareroot seedlings were more affected by the fertilizer injury than were container seedlings. A possible explanation is that container seedlings generally developed more new roots than did bareroot seedlings. Therefore, losing some roots to fertilizer injury would not be as detrimental to container seedlings as it would be to bareroot seedlings. The problem of root burn could be avoided by using a slow-release fertilizer.

Fertilizer had a positive effect on seedling vigor, stem height, and diameter, however. Within 3 weeks after application, it was apparent which seedlings had been fertilized. Fertilized seedlings of both stock types were greener and had greater bud extension than unfertilized seedlings. The height and diameter of the container seedlings generally showed a greater growth response to fertilization than did bareroot seedlings (table 2), which again may be explained by the better new growth of the container seedlings.

Effect of fertilization on deer browsing and frost damage. The effects of fertilizer on height and diameter were partially

Figure 2—*Unfertilized (left) and fertilized (right) knobcone × Monterey pine seedlings after the third growing season.*

masked by deer browsing and frost, however. Seedlings were affected differentially by deer browsing and frost, depending on whether or not they were fertilized. For both stock types, the differences in vigor, stem height, and diameter between fertilized and unfertilized seedlings were compounded by deer predation. Deer damaged tops of more fertilized seedlings than unfertilized seedlings, 16 versus 8%, respectively. This may have occurred because fertilized seedlings, with their large, more succulent tips, were more attractive to deer (fig. 2). A late frost at the beginning of the third growing season injured the growing tips of 32% of the fertilized seedlings, compared to only about 5% of unfertilized seedlings. Lateral buds quickly expressed dominance on injured seedlings, however, so apparently little height growth was lost.

Spring planting versus fall planting. The field performance of container seedlings was the same whether they were planted in the spring or fall, as there were no significant differences between planting season and seedling survival rates or between stem height or diameter growth rates. No bareroot seedlings were fall-planted, because no dormant stock was available.

Management Implications

Research indicates that harsh sites such as the scar left after the construction of Trinity Dam can be revegetated without extraordinary methods if

1. **The correct species is planted.** Previous efforts to revegetate the scar indicated that knobcone x Monterey pine seedlings would grow on this site.
2. **Seedlings have high survival and growth potential.** Container seedlings of this hybrid should be planted because they have a higher capacity to develop new roots than bareroot seedlings, and

therefore have a higher capacity to survive and grow. Also, container seedlings can be successfully planted in the spring or fall, whereas bareroot seedlings, because they do not harden enough to allow fall lifting, are available only for spring planting.

3. **Nutrient requirements of seedlings are met.** For rapid establishment of seedlings, a slow-release fertilizer should be applied at the time of planting. A quick-release fertilizer such as that used in the study is not recommended on rocky sites because of leaching, which results in burning of the roots and loss of nutrients. The fertilizer should be formulated to overcome the nutrient deficiencies gaps of the site.

4. **Seedlings are protected against deer browsing.** Fertilized seedlings must be protected from deer because of the increase in browsing following fertilizing. Fertilized seedlings are more susceptible to late frost damage than unfertilized seedlings, but fertilized seedlings also appear to recover faster from injury than unfertilized seedlings.

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