Causes of Mortality in Outplanted Ponderosa Pine Container Seedlings in the Southwest

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*Rocky Mountain ponderosa pine (*Pinus ponderosa *var.* scopulorum *Engelm.) seedlings, raised in containers under a low N regime, were planted on a 1-year-old burn in central Arizona and were protected from wildlife. Survival after 1 year was 90%. There were no differences in survival between naturally shaded and unshaded plots. Mortality was caused primarily by frost heaving and drought.* Tree Planters' Notes 40(3):16 19; 1989.

Regenerating Rocky Mountain ponderosa pine (*Pinus ponderosa* var. *scopulorum* Engelm.) in the Southwest (Arizona, New Mexico, and southwestern Colorado) is difficult because of drought conditions at critical times during the year, competing vegetation (primarily perennial grasses), browsing mammals, and slow juvenile growth.

Difficulty in obtaining regeneration is also closely related to soil types. Forest soils in the Southwest are volcanic (derived from basalt rocks) or sedimentary in origin. Natural regeneration on volcanic soils is almost nonexistent because of frost heaving and drought (5,7). It is easier to get natural regeneration on sedimentary soils when correct procedures are followed (8), although these soils will also heave, especially if they are compacted (3). Larger bareroot and container seedlings do not heave readily on either soil (3,10). Therefore, planting seedlings on both soils is successful when established guidelines are followed (7,11). Correct procedure, however, is not always observed.

Often, essential steps, such as site preparation or protection from grazing animals, are omitted. When this happens, low survival is inevitable. An additional factor, recently observed with bareroot stock, is that survival may be inversely related to size of planting stock. Larger seedlings survive at lower rates, especially during dry years, than smaller trees (4). Poorer survival of larger trees presumably occurs because of a greater transpiring surface, which would be detrimental during droughts.

Results from container plantings have been quite varied. Reasons for failure can be attributed, to a great extent, to small container size and faulty practice in raising the seedlings. Often, because of poor planning, crops are sown at the wrong time and delivered to the planting site while still in succulent condition. If this occurs while temperatures are still well below freezing, mortality with be high.

This note reports the results of planting of a 16-ha burn on the Fort Valley Experimental Forest.

Methods

Site. The planting site is approximately 26 km northwest of Flagstaff, AZ, and is in the ponderosa pine/Arizona fescue (*Pinus ponderosa/Festuca arizonica*) habitat type, Arizona fescue phase (2). The elevation is 2,195 m, and the site is mostly level. The soil is well developed and classified as a Mollic eutroboralf; soil texture is a silt loam (6). Outcroppings of basalt rocks occur throughout the site. A few small areas could not be planted because of rocks.

The prefire stand was composed, primarily, of an old-growth ponderosa pine overstory with an understory of poles that originated in the bumper seed crop year of 1919. In June 1982, a fire that started just outside the Experimental Forest crossed the boundary and burned approximately 16 ha. Most of the stand trees were killed by the fire. Dead trees were left standing after the fire.

Seedlings. Seedlings were raised in the Bureau of Indian Affairs (BIA) greenhouse at McNary, AZ. Seeds collected earlier, just north of the Experimental Forest, were shipped to the greenhouse in August 1982. Seeds were sown in Tinus Rootrainers® (492 cm^3), manufactured by Spencer-LeMaire, Ltd., Canada. Substrate consisted of a 50:50 (v/v) mixture of peat moss and vermiculite. Totes (a tote contains 40 cavities) of seedlings were watered regularly with plain water until after germination. At that time, Peter's 15-30-15 water-soluble fertilizer was applied regularly in the irrigation water to provide 40 parts per million (ppm) N. Peter's S.T.E.M. fertilizer containing micronutrients also was added to the irrigation water, as was Sequestrene 330, an iron supplement. Each 100 liters of fertilizer solution contained 4.26 kg NPK (15-30-15), 32 g S.T.E.M., and 900 g Sequestrene 300 (1).

Seedlings were raised for 12 weeks in the greenhouse under constant light and an environment enriched with CO_2 then were gradually hardened off in the greenhouse by turning off supplemental lighting and the CO_2 generator. Temperatures were dropped 5.6 °C every 2 weeks, and watering was greatly curtailed. Fertilization also was stopped.

In mid-December, seedlings were moved outside to a lathhouse, where they were not watered until spring. After a heavy watering, seedlings again were stressed. Fertilizer was not applied until after tops had begun to grow.

Site Preparation. Many open areas of the burn contained heavy stands of perennial grasses, primarily Arizona fescue and mountain muhly *(Muhlenbergia montana*). In the shade of dead poles, various annual grasses and forbs began to invade in the spring of 1983.

During the spring of 1983, all areas with live vegetation were sprayed with glyphosate (Roundup®) at a rate of 3.36 kg active ingredient/ha using Herbimicron sprayers.

Planting. Seedlings were transported to the Experimental Forest in June and stored in an outdoor lathhouse, where they were watered and fertilized regularly. Seedlings were held in the lathhouse until August 8 when planting began. On the afternoon of August 8, a heavy rain drenched the site.

Trees were planted under contract on a 2.44- by 2.44-m spacing. The contractor was given the option of using KBC bars, hoedads, or augers in planting trees. Trees were planted by all three methods, but augers were not used extensively because of rocky conditions.

Elk (*Cervus elaphus*) have been a particular problem in the area. Therefore, after trees were planted, Vexar® seedling protectors, 7.6 by 45.7 cm, were placed around each seedling, held in place with two number-9 wire pins.

Sampling. In October 1983, five open areas and five areas under standing dead poles (natural shade) were chosen for sampling. The 10 sampling areas were well distributed throughout the planting site. It was not possible, however, to pair shaded and unshaded plots. In each area, 50 trees were selected for survival checks and were marked with wire flags. Survival was checked in October 1983 and three times in 1984. Survival rates were determined using the following grading system.

1. Trees alive and growing.
2. Trees alive, but not growing.
3. Trees dead.

A t-test for unpaired plots was used to determine differences in survival and mortality between shaded and unshaded plots.

Results and Discussion

Overall, survival 14 months after planting was 90%. Although survival under natural shade was 4% greater than in the open, the differences were not significant (P = 0.20). In the open, 50% of the mortality was from frost heaving (16 trees), compared to 30% (6 trees) under natural shade. Percentage of trees planted that heaved, however, was 6.4 in the open and 2.4 under natural shade (table 1). On this same site, Larson (9) found heaving of first-year ponderosa pine seedlings established from seed to be exceptionally heavy. Almost all of nearly 1,000 seedlings heaved out of the ground between October 1957 and April 1958. The fact that seedling transplants in this study heaved at a low rate confirms findings by Schramm (10) that larger conifer seedlings heave less than smaller, newly germinated seedlings.

Drought ranks as the second greatest cause of mortality (table 1). Throughout the planting period, heavy rains fell on the area. From July 26 to October 13, 20.3 cm of precipitation was recorded. Approximately 15.2 cm fell in September. After the fall wet period, however, conditions became very dry. During the winter of 1983-84, only 63.5 cm of snow fell, approximately 25% of expected snowfall. In addition, the spring of 1984 was one of the driest on record. Beginning with the summer rains in July 1984, precipitation has been well distributed and soil moisture has been excellent.

Despite the fact that seedlings were protected by Vexar tubes, several trees were browsed, primarily by elk, because protectors either were knocked over by animals or the pin holding them heaved from the ground. About the same number of trees were browsed in the open and in the shade (tables 1 and 2).

Although there are no controls with which to make comparisons, observations over many years indicate that this plantation was successful because all factors necessary to ensure success were present. Seedlings were grown from seed collected locally, raised to a proper size, and conditioned to withstand moisture stress. Competing vegetation was eliminated, and seedlings were protected from browsing mammals. All of these factors should be considered when initiating planting projects in the southwestern United States.

Table 1—*Mortality of ponderosa pine container seedlings planted in the open and under natural shade on a recent burn in central Arizona*

Cause of mortality	Open			Natural shade		
	Mortality			Mortality		
	No.	Percent	P	No.	Percent	P
Frost heaving	15	50.0 a	0.05	6	30.0 a	0.05
Mammals	1	3.33		2	10.0	
Drought	8	26.67 a	0.03	4	20.0 a	0.03
Misc.	6	20.0 a	0.50	8	40.0 a	0.50
Total	30	100.0 a	0.20	20	100.0 a	0.20

Treatments with the same letter in common do not differ significantly at the level indicated. Comparisons were only made where large numbers of seedlings were involved or where there appeared to be differences.

Table 2—*Damage to ponderosa pine container seedlings planted in the open and under natural shade on a recent burn in central Arizona*

Cause of damage	Open			Natural shade		
	No. trees	Percent planted	P	No. trees	Percent planted	P
Frost heaving	1	0.04		2	0.08	
Mammals	52	20.8 a	>0.50	55	22.0 a	>0.50
Total	53	21.2 a	>0.50	57	22.8 a	>0.50

Treatments with the same letter in common do not differ significantly at the level indicated. Comparisons were only made where large numbers of seedlings were involved or where there appeared to be differences.

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