Windbreak Tree Establishment in Semi-Arid Agricultural Regions of New Mexico

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Introduction

Windbreaks are plantings of trees and shrubs for the purpose of reducing the deleterious effects of strong winds. The concept of establishing windbreaks or shelter belts was first documented in the 1600s (Le Sueur 1951). The concept has become more comprehensive over time. A windbreak is now viewed as an agroforestry system providing potential secondary benefits. Agroforestry is a method of integrating forestry and agricultural practices to achieve diversification and increased income-generating opportunities.

The reasons for establishing windbreaks differ throughout the world. Windbreaks in arid and semi-arid regions of developing countries are often mistakenly avoided due to the marginal prospect of agricultural productivity and the lack of quantitative cost/benefit information (Muthana 1986). In western Rajasthan, India, water shortages and wind erosion are the most serious problems in agriculture production, and windbreaks are very effective in deterring soil erosion and increasing crop yields (Gupta 1983). In arid portions of northern India, studies have shown improved crop productivity under windbreak canopies for nonirrigated crops (Muthana 1986). In northern China, windbreaks have been used for many generations to protect sandy soils from erosion and to reclaim otherwise unproductive land in order to accommodate the growing population (Chepil 1948).

The economic benefit of a windbreak varies with windbreak design, type of windbreak (for field, farmstead, or feedlot), and environmental parameters such as climate and soils. However, the USDA's Natural Resources Conservation Service has estimated some of these values (USDA 1992). Reported improvements in crop production range from 6 to 44%, while soil erosion was reduced from 50 to 100%. Farmstead windbreaks can enhance property values and reduce energy consumption by as much as 40% depending on the climate. The influence of windbreaks on feedlots can lead to reported feed savings of 10 to 30%. The economic influence of windbreaks on wildlife are more difficult to determine but can be more pronounced. For example, if the windbreak provides a critical habitat feature (such as food, cover, or nesting area) the presence of the windbreak will allow the wildlife to occur in the area.

The Dust Bowl of the 1930s focused attention on soil erosion problems in the United States. The drought conditions that decimated the soil-holding vegetation, the perpetual wind, and the working of the soil contributed to the increased soil erosion. In 1933, President Roosevelt and Robert Y. Stuart, chief of the Forest Service, proposed a plan that would establish shelter belts from the Canadian border to northern Texas (Bonnifield 1979). This project came to be known as the Prairie States Forestry Project. This federally funded program was one of the grandest tree-planting programs in the United States. From 1935 to 1942, more than 29,000 km (18,000 miles) of windbreaks were planted (Tibke 1986).

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There are an estimated 270,000 km (170,000 miles) of windbreaks in the United States today (Tibke 1986). However, still more windbreaks need to be established in the United States. A report released in 1986 maintains that in the 10 Great Plains states, including New Mexico, 1.3 million ha (3.3 million acres) of land were damaged by wind, 94% of it crop land (Tibke 1986). Today in the United States, windbreak planting continues to surpass windbreak removal. Again, this is due, in part, to federal assistance provided through programs such as the Forest Stewardship Incentives Program and the Environmental Quality Incentives Program. To improve the success of these windbreak plantings and to improve the cost efficiency of these programs, researchers at New Mexico State University and elsewhere are examining factors that can improve seedling establishment in arid and semi-arid areas.

Container-grown seedlings are routinely used in arid zone afforestation (Goor and Barney 1976; Fisher and Widmoyer 1978). Several studies have illustrated the superior performance of container seedlings in terms of survival and growth in plantings with limited available moisture (Hite 1974; McDonald and Cosens 1980; Amidon et al. 1981; Hobbs et al. 1981). This improved performance may be due to an undisturbed root system, which results in reduced transplant shock (Kinghorn 1972; Romero et al. 1986). When comparing container seedlings to bareroot seedlings, the overall growth of the container seedlings is frequently greater (Gillham and Parton 1991). However, several factors can affect this performance benefit, including seedling stock size and site preparation.

Container size influences seedling size and attributes, and has been shown to affect outplanting performance. Seedlings grown in small containers usually have small stem diameters and root/shoot ratios (Simpson 1991). In contrast, seedlings produced in larger containers have larger stem diameters and root/shoot ratios (Thompson 1981; Van den Driessche 1984; Simpson 1991). These qualities of seedlings grown in larger containers may help reduce transplant shock. In both late summer and spring plantings of longleaf pine in Jasper, Texas, seedlings grown in 128 ml (8 cubic inch) containers outperformed seedlings grown in 64 ml (4 cubic inch) containers by 101% and 55%, respectively (Amidon et al. 1981).

Failure of many tree plantings in the Great Plains has been attributed to poor site preparation and failure to maintain trees after they are planted (Nickerson 1990). Site preparation is the manipulation of the planting site to increase transplant survival. [redacted] he most appropriate technique depends on several factors including climate, soil characteristics, topography and tree species.

Few studies have compared different site preparations in arid and semi-arid regions. In the southwestern United States, where moisture stress is the primary limiting factor, the success of less intensive site preparation can vary (Fisher and Montano 1977). The reinvasion of competing vegetation often inhibits the release of the seedlings from the initial site preparation treatment. In semi-arid western Africa, soil tillage is used successfully as a site preparation for establishing trees (Nicou 1986). Tillage increases the porosity of the surface soil layers and improves water-holding capacity. Lantagne and Burger (1987) used a rain harvesting system to improve transplant survival in the southern Piedmont. Brown et al. (1992) discussed a site-preparation treatment that used a woven polyethylene fabric (synthetic mulch) in combination with a V-ditch water-harvesting system to improve survival in the southwestern United States. In southwestern Mexico, black polyethylene mulches have been successful in increasing the growth of perennial crops (Stapelton and Garza-Lopez 1988).

The challenge to establishing windbreaks in New Mexico is to determine the ideal combination of seedling stock size and site-preparation techniques to optimize survival while minimizing costs. The objective of this study was to determine the optimum combination of seedling size (stock type) and site-preparation technique to maximize early performance and reduce costs.

Methods

We used two conifer species common to windbreaks in southern New Mexico: eldarica pine (*Pinus brutia* subsp. *eldarica*) and Arizona cypress (*Cupressus arizonica*). Seedlings were propagated from seed, and four container volumes were used to generate four stock sizes within each species. The container volumes were 115, 164, 262, and 656 ml (7, 10, 16, and 40 in^3) (Steuwe and Sons Inc., Corvalls, OR).

Four site-preparation treatments were evaluated. These treatments included a 2-meter (6.6 ft) wide synthetic weed barrier, a 2-meter wide V-ditch, a combination of the 2-meter wide synthetic weed barrier laid over a 2-meter wide V-ditch, and an undisturbed control. The V-ditch site preparation treatment involves making a shallow (10 cm, or 4 inches, deep in the center) ditch 2-meters wide. This was done with two passes using a grading blade mounted on the back of a farm tractor. The synthetic weed barrier was a tightly woven, black, synthetic burlap, which allows water to penetrate but restricts weed growth. On treatments with weed barriers, the seedlings were planted, then the weed barrier was laid down by hand and stapled in place.

Three planting sites representing three different agricultural regions in New Mexico were used in this study. These sites included NMSU's Agricultural Science Center at Artesia, Agricultural Science Center at Los Lunas, and Agricultural Science Center at Tucumcari. The Artesia planting site was an abandoned small grains field with a loamy soil. The Los Lunas site had native shrub vegetation, primarily sage, and was a loamy sand soil. The Tucumcari site had been a pasture with native vegetation and some exotic grasses and was a sandy loam soil.

The study sites were planted in May 1995. At the Los Lunas and Artesia planting sites, after the seedlings were planted and site preparation treatments installed, the seedlings were irrigated once with 75 mm (3 inches) of water. At the Tucumcari site, no supplemental irrigation was provided, but the site received 51 mm (2 inches) of precipitation in the 72 hours following planting. Each species x stock type x site preparation treatment was replicated at each site in a randomized complete block design with 3 blocks consisting of a 10-tree row plot per treatment combination. Seedling survival was measured at one and six months following planting.

Results

The influence of the treatments on the survival and growth of the seedlings varied among the three sites. Several factors unique to each site contributed to this variability. However, the greatest overall influence was the prolonged drought, which occurred statewide during the six months following the planting of the seedlings. The three sites received less than 16 mm (0.6 inches) of total precipitation during these six months with the Artesia site being the driest, receiving less than 8 mm (0.3 inches) of precipitation. This drought represented a worst case scenario for arid land tree establishment.

Early survival (30 days following planting) at the Artesia site was greater than 90% for eldarica pine in all site-preparation treatments except the weed barrier alone treatment, which had an 86% survival (fig. 1a). A similar trend in early survival was seen with the Arizona cypress seedlings, however, overall survival was slightly lower, ranging from 70 to 96% (fig. 1a). After six months, only the control site preparation treatments had a significant decrease (20%) in survival in eldarica pine, while Arizona cypress at the no-site-preparation treatment showed an increase in mortality greater than 10%. In both species, the larger container sizes showed greater survival after one growing season. These differences were not seen in the early (30 day) evaluation of survival (fig. 1b).

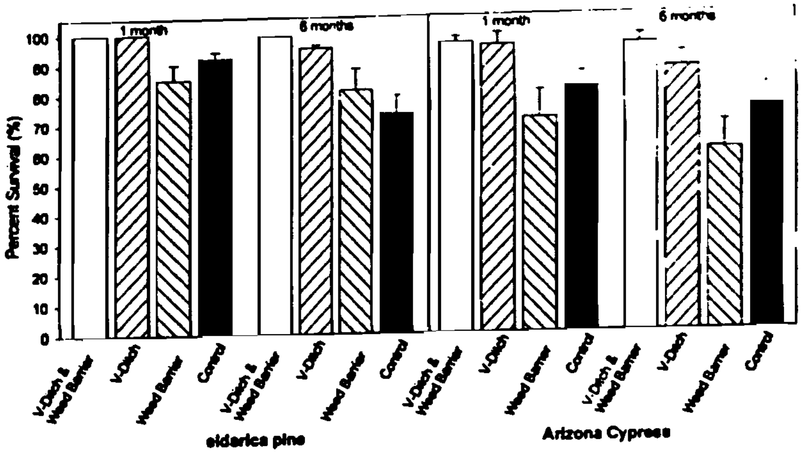

Figure 1a. Influence of site preparation on early survival (30 day) and survival at the end of the first growing season for eldarica pine and Arizona cypress seedlings growing in Artesia (mean ± 1 std. error).

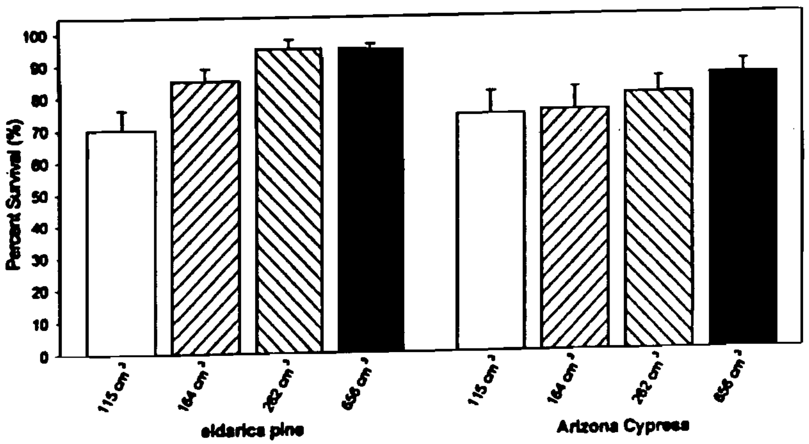

Figure 1b. Influence of stock size on survival of eldarica pine and Arizona cypress at the end of the first growing season in Artesia (mean ± 1 std. error).

At the Los Lunas planting, a problem with the staples holding down the weed barrier resulted in low early (30 day) survival of seedlings in the weed barrier treatments. However, after that problem was corrected, survival of both species at the end of the growing season was improved in the more intensive site preparation treatments (fig. 2a). The most intensive site preparation treatment, V-ditch plus weed barrier, had decreases in survival of 4% and 6%, respectively, in Arizona cypress and eldarica pine from the 30-day evaluation to the end of the growing season (fig. 2a). During this period, the mortality of seedlings in the control site preparation treatment increased more than 20% in both species. As was found at the Artesia planting at the end of the growing season, the larger seedlings of both species had greater survival than smaller seedlings (fig. 2b).

All three site-preparation treatments improved the survival of both the Arizona cypress and eldarica pine 30 days after planting at the Tucumcari site (fig. 3). Eldarica pine seedlings planted in the control site preparation showed 95% mortality. Arizona cypress mortality in the same treatment was 99% after 1 month. At the end of the growing season, mortality was high in all site-preparation treatments. However, those seedlings growing in the treatments containing the weed barrier, specifically those seedlings growing in the V-ditch plus weed barrier treatment, had the greatest survival (fig. 3). As was found at both the other planting sites, the larger seedlings had better survival rates at the end of the growing season.

Discussion

The results of this study indicate that seedlings can be established in arid and semi-arid regions of New Mexico with only one supplemental irrigation immediately following planting. While the responses varied among the three different test plantings, it appears that larger seedlings have greater survival rates.

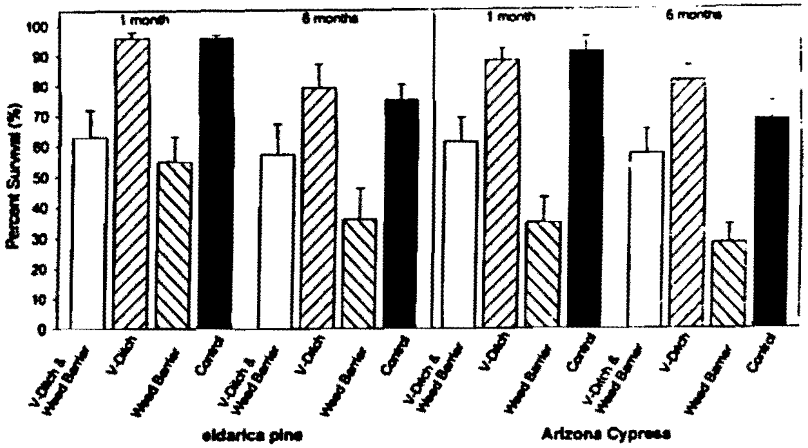

Figure 2a. Influence of site preparation on early survival (30 day) and survival at the end of the first growing season for eldarica pine and Arizona cypress seedlings growing in Los Lunas (mean ± 1 std. error).

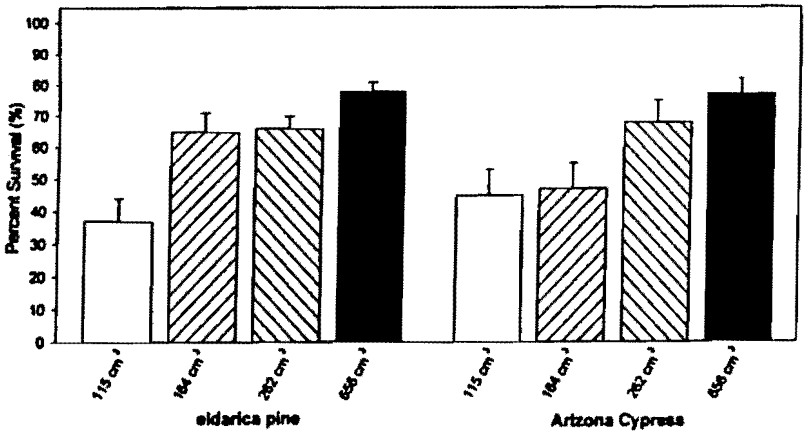

Figure 2b. Influence of stock size on survival of eldarica pine and Arixona cypress at the end of the first growing season in Los Lunas (mean ± 1 std. error).

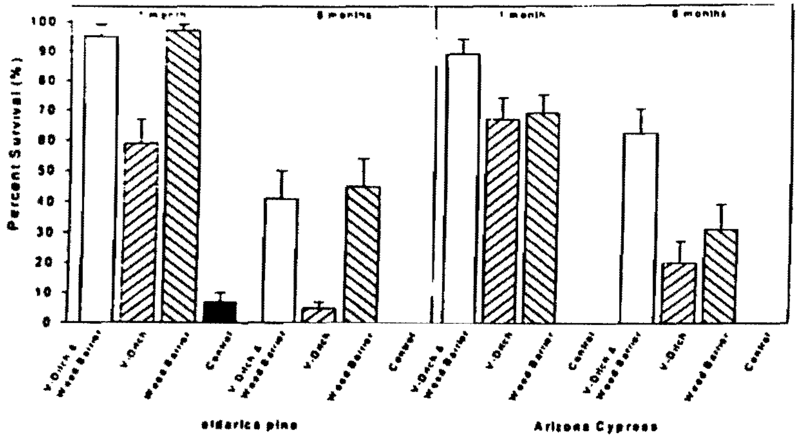

Figure 3. Influence of site preparation on early survival (30 day) and survival at the end of the first growing season for eldarica pine and Arizona cypress seedlings growing in Tucumcari (mean ± 1 std. error).

The lack of consistent effects of the V-ditching and weed barrier treatments alone and in combination may be attributed to the lack of appreciable precipitation during the first growing season. Ideally, the V-ditching system will capture and channel to the seedlings the moisture from the episodic, heavy rains characteristic of New Mexico's climate. This, however, did not occur during the drought conditions of the study period. Synthetic weed barriers, such as the one used in this study, are very effective at controlling competing vegetation and retaining soil moisture near the seedling (Al-Qurashi 1997). However, with little new moisture, and given the low water-holding capacity of two of the three sites evaluated in this study, the beneficial effects of the weed barrier were not as pronounced.

In an evaluation made three growing seasons after planting of the larger stock type (656 ml, or 40 in^3, container), Arizona cypress seedlings planted at the Los Lunas site had very little change in mortality (< 2%) in seedlings in the combined V-ditch and weed barrier treatment (Al-Qurashi 1997). At this evaluation, less than 10% additional mortality was observed in the other two site preparation treatments, while seedlings growing in the control site had a large increase in mortality, with less than 40% of the seedlings remaining (Al-Qurashi 1997).

New Mexico faces the omnipresent threat of soil erosion. Soil texture, arid and semi-arid climates, and persistent winds contribute to the potential for wind erosion. Wind erosion damaged 347,000 ha (857,800 acres) in New Mexico between November 1983 and May 1984 (Huszar and Piper 1986). This damage can be broken into two components: off-site costs and on-site costs.

Costs of off-site wind erosion include increased maintenance and damage caused by wind erosion away from the source of the erosion. Costs of on-site wind erosion are the costs associated with decreases in soil fertility and production, and increases in operation costs. In New Mexico, annual costs of off-site wind erosion are approximately $465 million compared, with $10 million in costs of on-site erosion (Huszar and Piper 1986), so costs of off-site wind erosion are considerably higher than on-site costs. Off-site wind erosion constitutes an estimated 86% of the total wind erosion in the state (Huszar and Piper 1986). Windbreaks have the potential to greatly reduce these losses and costs in New Mexico.

Currently in New Mexico, the site preparation treatment most commonly recommended for establishing windbreaks in arid and semi-arid regions involves using the V-ditch/weed barrier treatment in conjunction with drip irrigation. These plantings typically have survival rates greater than 90% after the first growing season (Harrington, unpublished data). The drip irrigation, while improving survival, can increase the total cost of a windbreak planting by more than 30% (table 1), assuming an adequate water source. If a nearby water source is not available, then costs associated with the drip system can easily exceed 50% of the total project cost. In other plantings using the V-ditch/weed barrier site preparation in central and northern New Mexico, a survival rate over 90% has been observed in years with typical precipitation patterns (Harrington, unpublished data, unreferenced). Using drip irrigation systems reduces the risk associated with losses due to severe droughts such as was found in this study. But the cost of this "insurance" must be weighed against the cost of replanting and the frequency of droughts.

Table 1. Material cost per 30 m (100 feet)[a] associated with the establishment of windbreaks in New Mexico. The large variations in labor and equipment costs throughout the state precluded their incorporation in this table.

	Container size			
Site preparation	115 ml ($)	164 ml ($)	262 ml ($)	656 ml ($)
No site preparation	6.25	9.38	18.75	25.00
V-ditch (VD)	21.25	24.38	33.75	40.00
Weed barrier (WB)	46.25	49.38	58.75	65.00
Drip irrigation[b] (DI)	36.25	39.38	48.75	55.00
VD & WB	61.25	64.38	73.75	80.00
VD & WB & DI	91.25	94.38	103.75	110.00

[a] *Reflects 1997 cost of a single-row wind break with seedlings planted at 2.4 m (8 foot) intervals; does not include tractor or equipment costs.*

[b] *Drip irrigation cost estimate includes cost of single-line emitters but not pumps, special fittings, or filters and does not include maintenance or monitoring.*

Controlling wind erosion is critical in areas with little precipitation, frequent droughts, and high winds. The hazards inherent in this type of climate make the sustainability of an agricultural community, like New Mexico's, short-term. In regions with this type of climate in combination with soils with low water-holding capacity, perennial vegetation should be optimized. Afforestation of these areas is one solution. The presence of the trees can create microclimates more amenable to sustainable agricultural systems.

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