RESPONSE OF EIGHT HARDWOOD TREE SPECIES TO IRRIGATION, MULCH AND SHADE ON A TEXAS LIGNITE MINE[1]

by

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Abstract. Eight angiospermous tree species were planted on a Texas lignite mine to test for survival and growth as influenced by irrigation, mulch and artificial shade. The species were lacebark elm (Ulmus parvifolia), green ash (Fraxinus pennsylvanica), Washington hawthorn (Crataegus phaenopyrum), common persimmon (Diospyros virginiana), yaupon (Ilex vomitoria), American sycamore (Platanus occidentalis), eastern redbud (Cercis canadensis), and Shumard oak (Quercus shumardii). Trees were planted in a 2x2x2 factorial arranged as a split plot in six blocks, each 0.40 acres (0.16 hectares) in size. Results for the 1989 growing season showed that irrigation significantly (P=0.05) increased survival of most species (61% versus 35%). Mulch and shade had no effect on survival (P=0.05). The research was continued during the 1990 growing season with irrigating of only half of the plots that were irrigated in 1989. Mulch and shade were removed as treatments since they had no effect on survival during 1989. Therefore, 1990 treatments consisted of: (1) non-irrigated for 1989 and 1990, (2) irrigated in 1989 but not in 1990, and (3) irrigated in both 1989 and 1990. Results after the 1990 growing season showed that irrigation during a second growing season basically had no effect on survival. The average survival across all eight species when irrigated only in 1989 was 41% as compared to 42% when irrigated in both 1989 and 1990. Trees never irrigated survived at the rate of 25% after two growing seasons. As in 1989, response across species varied but with no species did second-year irrigation substantially increase survival. The research provided a test of a simple, mobile irrigation system that can economically be applied to similar situations.

Additional Key Words: surface mining, water use

Introduction

Nearly 2.5 million acres (one million hectares) have been leased in Texas for surface mining of lignite coal. Texas state law requires that surface mined areas be returned to their approximate original contour and that permanent vegetation be established. Native vegetation is preferred where possible, and much interest exists in establishing woody species offering wildlife and aesthetic appeal. Research elsewhere has shown that angiosperms hold promise for revegetating reclaimed areas (Vogel 1981, McMinn et al. 1982, Cunningham and Wittwer 1984) but most research in Texas has dealt with chemical and physical characteristics of the overburden (Dixon et al. 1980) or establishment with herbaceous species (Hons et al. 1980, Chichester and Hauser 1984, Skousen and Call 1987, Skousen et al. 1990). Published research dealing with woody plant establishment on lignite minesoils is limited (Davies and Call 1990). For a seven-year period beginning in 1981, scientists in the Department of Forest Science, Texas A&M University (TAMU), collaborated with the Texas Municipal Power Agency (TMPA) on several experiments designed to investigate the effects of species, fertilization, mycorrhizae, slope, and topsoil depth on revegetation with woody vegetation. Although some treatments provided moderate success, most resulted in less than 50% survival

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and unacceptably poor growth. At the close of this research, it was obvious that water was the most limiting factor at Gibbons Creek Lignite Mine (GCLM) and that most attempts at revegetation in normal weather years would yield poor results without supplemental water.

In late 1988, personnel at TMPA recommended that TAMU researchers develop an irrigation system for woody species establishment. A research project was conducted between April 1989 and March 1991 to develop a cost effective, minimum maintenance strategy involving irrigation for establishing woody vegetation on the reclaimed areas of GCLM, Carlos, Texas. The system was to be used after overburden was returned to the mined areas and soils were stabilized with a herbaceous cover. The system had to be inexpensive, re-useable, could not rely upon supplemental power, had to involve minimum maintenance, and be easily moved among sites after each growing season. Water was to be obtained from a source near the plantations. Such a system was designed and tested, along with supplemental treatments, for a two-year period at GCLM. The objective of this paper is to describe the efficacy of such a system to sustain woody species.

Materials and Methods

Gibbons Creek Lignite Mine lies partly in the Post Oak Savannah and Blackland Prairie regions of Texas. The climate is classified as subhumid with a growing season of about 275 days and an average annual rainfall of 39.32 inches (997 mm) at Carlos (10-yr mean 1981-1990). However, the area is characterized by periods of summer drought and a relatively high average maximum temperature of 93.6 °F (34.2 °C) for the period of June through August. Rainfall for the June to August period averages 9.79 inches (249 mm) with a recorded maximum of 22.53 inches (572 mm) and a minimum of 0.62 inches (16 mm); soil moisture deficits are common during the latter part of the growing season. Such environmental conditions pose a substantial growing season stress on woody vegetation planted on the exposed areas of a reclaimed surface mine.

On April 1, 1989, research was begun to test the effects of irrigation, artificial mulch, and artificial shade on the survival of eight woody species planted at GCLM. We hypothesized that in addition to supplemental water, protection from excessive solar irradiation and associated lethal temperatures, and reduction of competition from herbaceous vegetation would promote greater woody plant survival.

Eight species of trees and shrubs were tested: lacebark elm, green ash, Washington hawthorn, common persimmon, American sycamore, eastern redbud, yaupon, and Shumard oak. Lacebark elm is commonly planted in the area as an ornamental and is native to China, Korea and Japan. Washington hawthorn is native to areas just east of Texas but is also widely planted as an ornamental. All other species are native to the study area. All species were planted as bare-root stock except yaupon and Shumard oak which were containerized. Species choice was based upon knowledge of the vegetation present on the site before mining and upon plant availability.

The plants were established in mottes to facilitate irrigation and to establish a community that would succeed itself and spread laterally over time. Also, judicious placement of mottes would provide a corridor for wildlife movement across the large open areas. Six plots (mottes), each measuring 144 feet by 120 feet (43.9 m X 36.6 m), were installed. Plots were oriented to facilitate gravitational water flow through the irrigation system. The experimental design was a split-split plot with irrigation treatment as the main plot, shade and mulch in a 2 X 2 factorial sub-plot, and species as the sub-sub plot. The shade and mulch factors were considered equally important so this design was chosen which allowed the shade and mulch treatments to be tested with equal precision since they were arranged in a 2 X 2 factorial in the sub-plots. Thus, the species factor was tested with greatest precision; shade and mulch with intermediate precision; and the irrigation factor with least precision. All eight species were located in each shade/mulch subplot in six eight-plant rows, each row containing all species (Figure 1).

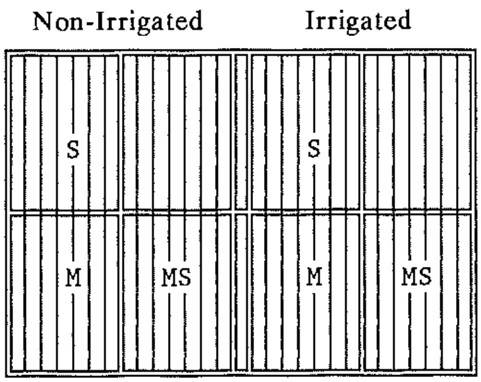

Figure 1. Generalized design of one plot. The single lines in each plot contain eight plants representing eight species. All treatments and species were randomly assigned in the field.

From April 1 to April 11, 2304 seedlings were hand planted on a 6 X 6-foot (1.8 X 1.8 m) spacing. Planting was done with a "pit-planting" technique; i.e., a small pit (mini-catchment) was dug, all soil was removed, the seedling was carefully situated in the hole, and the soil placed back around the roots in a manner that left the seedling's root/shoot interface at the original nursery soil line, but with the new soil line at about six inches (15 cm) below the general, surrounding soil level. This was done to create a depression for rainwater collection. Observation after several rainfalls confirmed that the depressions did indeed collect rain as standing water was seen in some depressions after the surrounding soil had dried. Those seedlings that died soon after planting were replaced. Plot replanting occurred between April 25 and May 2.

From April 13 to April 22, biodegradable mulch and tree shades were placed on the plots designated to be so treated. The mulch consisted of a 3 X 3-foot (0.9 X 0.9 m) biodegradable, grey synthetic made of polyresins guaranteed to photodegrade and disintegrate in 18 to 24 months. The material allows passage of air and moisture but inhibits herbaceous growth beneath it. The tree shades consisted of an 18 X 24-inch (46 X 61 cm) mesh envelope made from a non-toxic, photodegradable polyolefin that fit over a 12-gauge wire wicket that held the shade in a vertical position. The shades were considerably shorter than some of the taller species, but they were still able to shade the crucial root collar zone. Shading research by other workers has shown that most cambial damage from excessively high temperatures occurs at or near the seedling root collar (Helgerson 1990).

Plots were irrigated using a 1000-gallon (3780 l) fiberglass tank mounted on a two-axle trailer. The tank/trailer combination enabled relatively easy water transport to the sites and served as a reservoir during irrigation. The study was laid out so that two plots could be simultaneously irrigated. Irrigation water was pumped from a nearby pond into the tank with a gasoline-powered pump mounted on the trailer. Water pH averaged 9.3 with an electroconductivity of 0.25 mmhos.

Installation of the irrigation system was begun on May 13. The irrigation pipe consisted of black flexible polyethylene with an inside diameter of 0.60 inches (1.5 cm) and a wall thickness of 0.039 inches (0.1 cm). For each plot, 120 feet of pipe were placed aboveground on the 12 irrigated rows with an emitter at each plant. A main pipe located on the uphill side of the motte was connected to a series of laterals plugged at their ends. Such a system of trickle or drip irrigation has been used previously for ornamentals and orchard trees (Ponder and Kenworthy 1976a, 1976b, Ponder et al. 1981), for establishing shelterbelts or windbreaks (Dickey and Hintz 1987), and for foodcrop production (van't Woudt 1968), but little work has been done with mineland reclamation.

Precipitation was generous and fairly evenly distributed throughout May and June which made irrigation largely unnecessary during those months (8.20 inches (208 mm) compared to an average of 6.56 inches (167 mm)). However, in July environmental conditions became increasingly stressful as much higher temperatures and less rain (2.93 inches (74 mm) lead to greater irrigation demands. All six plots were irrigated during the following time periods: July 19 - 21, July 29 - 31, August 16 - 19, August 30 - September 3, and September 8 - 11. The interval between irrigations was approximately two weeks long, a first-time estimate since no prior knowledge was available. Emitters were checked for flow during each irrigation. Three days were usually required to water all six plots. Two of the six plots were watered simultaneously at each irrigation event, providing each seedling with approximately 2.5 gallons (9.45 l) of water. The distribution of water among plants was relatively equitable, although plants at higher levels received slightly less water than those at lower levels due to gravitational flow.

Survival assessments were conducted on July 10, August 11, September 11, and September 30. Deer were observed on the study area during most visits. Deer repellent was applied on August 3 after partially-eaten foliage was found on green ash. Armadillo excavations were noticed on the sandy plots where they dug small holes around the base of the seedlings. However, this caused no noticeable seedling mortality.

Research continued in 1990 to test second-year survival response. It was concluded at the end of the 1989 growing season that shade and mulch treatments did not significantly affect seedling survival and that irrigation had by far the most significant effect on survival. Therefore, mulch and shade were removed as treatments in 1990.

Four of the six plots were watered in 1990 thereby affording data on 2-year survival with irrigation in the first year only, with irrigation in both years, and with no irrigation in any year. The plots were watered seven times between May 28 and August 29, 1990. Survival in 1990 was assessed on June 1, July 19, and September 12.

Results and Discussion

As the 1989 air temperatures neared 100 °F (38 °C) and the time intervals between storms lengthened, survival began a rapid decline (Figure 2) with the most dramatic decrease occurring between July and August. Furthermore, treatment effects became more substantial as the summer progressed. For instance, the value of irrigation (Figure 2a) did not become apparent until August when the difference in survival between irrigated and non-irrigated plots became 20%. The merits of artificial mulch (Figure 2b) and shade (Figure 2c) never approached those of irrigation (Figures 2a and 3).

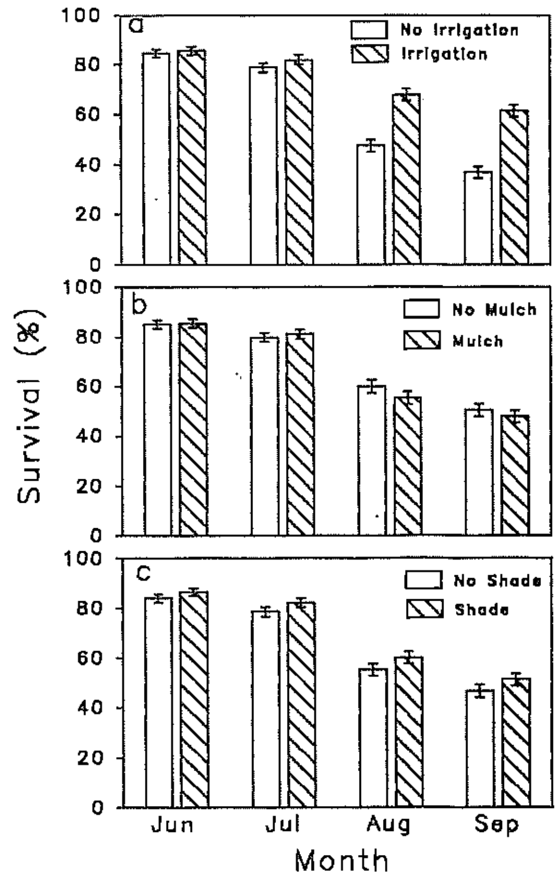

Figure 2. Main effects of irrigation (a), mulch (b), and shade (c) on survival of all species across the 1989 growing season. Vertical bars are standard errors.

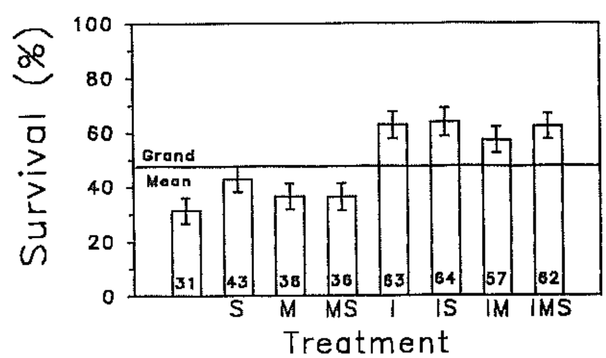

Figure 3. Treatment effects on 1989 survival of all species. Vertical bars are standard errors.

The September 30 survival assessment across all species showed smaller differences among subplot treatments (mulch, shade, shade/mulch and control) within irrigated plots than within non-irrigated plots, particularly for shade. The survival difference between the shade-only and the control treatments was 8.4% without irrigation and 4.0% with irrigation, which indicates that the value afforded by artificial shade was negated when supplemental water was added. The shade effect may not have been adequately tested, however, due to the heterogeneity of grass cover over the study sites. Some plots and portions of plots had a tall grass cover for most of the test period while other sections of the site were covered with only a short grass. In several locations, the artificial shade effect was nullified by the tall grass which also overtopped seedlings not receiving artificial shade. The grass may have protected seedlings in the no-shade treatments better than the artificial shade did in the short-grass areas, at least while rainfall was plentiful.

Four species had first-year overall survival rates that were higher than the grand mean of 47.6%. They were: lacebark elm (95%), Washington hawthorn (66%), green ash (50%), and common persimmon (51%). All show potential as hardy species for the test conditions. Other species exhibited little survival difference between May and June, but a distinct decrease in July after which survival decreased further but not as markedly.

Table 1 demonstrates that the effects of irrigation were not uniform across species. For instance, irrigation had little effect on lacebark elm which performed very well even without irrigation, but dramatically increased survival of other species. Sycamore and Shumard oak survival percentages were increased by three-fold, albeit to only 48% and 36%, respectively. However, survival of several species, such as green ash and Washington hawthorn, was increased from disappointingly low levels to quite acceptable values.

Three major points are obvious from survival counts made after the 1990 growing season (Table 1). First, irrigation offered substantial survival value during the first growing season. The increase in percent survival due to irrigation over all species was 25% during 1989 (60% irrigated versus 35% non-irrigated). Trees irrigated in 1989 only or in both 1989 and 1990, survived on average 15% better than trees not irrigated in either year. In other words, plots that were irrigated only in 1989 had an overall survival of 41% after 1990; those that were irrigated in

Table 1. Survival of tree/shrub species planted on a Texas lignite surface mine site as influenced by irrigation*. Data show both 1989 and 1990 survival of trees planted in 1989.

	1989 Survival		1990 Survival		
Species	IRR	NON-IRR	IRR in 89	IRR in 89 & 90	NON-IRR
	%		%		
Lacebark elm	98	91	99	95	95
Green ash	69	31	57	55	31
Washington hawthorn	83	48	47	42	25
Common persimmon	53	27	42	55	19
Yaupon	62	40	40	49	21
American sycamore	48	16	21	9	2
Eastern redbud	33	14	14	12	3
Shumard oak	37	11	8	15	3
MEAN	60	35	41	42	25

* 1990 survivals that exceed 1989 survivals are likely due to premature estimation of some trees as dead after the 1989 growing season that flushed in 1990.

both 1989 and 1990 had a survival of 42% after 1990; those irrigated in neither year had a survival of 25% after 1990. Second, at least in the two years tested, two consecutive years of irrigation offered no survival advantage over one year of irrigation. Third, although no species survived better without irrigation than it did with, results were extremely variable across species. For example, lacebark elm survived at or greater than 95% both with and without irrigation after two years. However, survival of American sycamore was only 9% after two years, even with irrigation. Also, American sycamore appeared to survive better after two years with irrigation only in the first year, but this may be an anomaly due to the variable nature of the data and environmental conditions in two different years. As expected, the only significant variables as shown by analysis of variance were species and irrigation.

Conclusions

Several conclusions can be drawn from the two years of experimentation at GCLM. Irrigation can be of substantial value in establishing woody vegetation on reclaimed lignite mine sites. The natural rainfall at GCLM is too sparse and too unreliable during the growing season to support successful revegetation efforts with most species. The irrigation done in these experiments afforded statistically significant survival advantages during both years of experimentation. Results may have been more substantial with shorter intervals between irrigation events. However, the fact that irrigation was significant even if done as infrequently as every two weeks is notable in itself.

Irrigation during the first growing season only was as effective as irrigation during the first two consecutive years. However, these data should not be used unqualified as annual weather will obviously affect results of any experiment run over two years. In other words, irrigation during a second year with an unusually hot and dry growing season may be very effective. Except for May and June, which were drier than normal, the growing season precipitation for 1990 was about average. The April through September rainfall was 21.81 inches (55.4 cm) compared to the average 21.52 inches (54.7 cm). Combined rainfall for May and June was only 53% of the normal for those two months.

Supplemental artificial mulch and shade, tested in 1989, did not afford any survival advantage. However, it must be stated that both may have been ineffectual because of experimental conditions. As previously stated, the effect of shade may have been reduced due to high grass cover which was taller than the tree shades in some plots. Furthermore, the grass cover was very sporadic and was very short in some plots and tall in others which confounded the effect of the tree shades. Herbaceous weed control was beyond the scope of this experiment. Artificial shade, at least basal shade, should be tested further in a more controlled experiment.

Mulch may have been ineffective because of the way in which the seedlings were planted. As previously described, seedlings stood in the bottom of a pit some 6 inches (15 cm) below the surrounding soil level. The mulch sheet was placed around the base of the seedling and actually acted as a covering of the pit to create a chamber. However, weed growth in the bottom of all pits was minimal, even without the mulch. Therefore, the pits themselves may have acted as a barrier to weed growth around the base of the seedlings.

Species choice is critical to successful regeneration. Survival across species was extremely variable with lower survival shown by those species that normally prefer more mesic environments. However, an obvious exception to this was green ash. Some species provided excellent results even without irrigation whereas others survived poorly even with irrigation.

Seedling growth was not included in the assessments since growth was usually imperceptible. More resources were likely expended in survival than in growth. Furthermore, some seedlings actually lost height as the growing season progressed due to drought-stress induced dieback and insect and mammal herbivory. It is suspected that seedlings that survive for two full years may be building root mass that may subsequently support shoot growth. Also, it is a growing habit of some seedlings to grow more in basal diameter for the first few years after planting, and then grow in height afterwards.

We suspected that some of the poorer survival rates may have been a result of inferior planting stock. Higher success would likely have been realized with large, one- or two-year-old containerized stock. Containerized stock will allow a longer planting season than will bareroot stock and suffer less from planting shock. However, they are more expensive and more difficult to transport, store and plant than are bareroot stock. Larger trees are generally more hardy, will overcome herbaceous competition sooner, tolerate insect and mammal herbivory better, and may withstand heavy spring rains which sometimes flood the planting holes and submerge smaller seedlings.

Recommended future work should involve irrigation scheduling so applications can be made based upon physiological and/or environmental factors. Ponder et al. (1984) irrigated nursery stock at 0, 25, 50, and 100% of net evaporation from a Class A pan evaporator and found significant responses.

In summary, drip or trickle irrigation showed promise for establishing angiospermous species on a lignite surface mined area and merits further investigation.

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