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16. Abstract

Mycorrhizae are fungi which form beneficial symbiotic associations with roots of a higher plant. Mycorrhizal fungi improve establishment and survival of plants on adverse sites. Construction or reconstruction of a highway produces an environment with tremendous environmental problems for revegetation, which limits plant establishment. An important objective inrevegetating highway rights-of-way is establishing a cover of desirable sod-forming grasses and other plants on roadsides, particularly on cut and fill slopes. Use of mycorrhizal plants is a potential technique for improving the establishment of highway vegetation under difficult Texas environmental conditions with minimal maintenance.

Over the past four years, cooperative research has studied use of mycorrhizal fungi in revegetating Texas highway roadsides near Austin, Winnie, Kerrville, and Nolanville. The study revealed that the two Austin highway sites, Kerrville Site II, and Nolanville site caused greatest revegetation problems due to slope, texture of the soil material and their potential for soil erosion. Tests to determine mycorrhizal activity were done with bioassays utilizing green sprangletop (Leptochloa dubia), sideoats grama 'El Reno' (Bouteloua curtipendula) and bermudagrass (Cynodon dactylon). Bermudagrass showed the greatest mycorrhizal colonization which could be of practical importance in ultimately reducing fertilization practices of bermudagrass stands. Green sprangletop, sideoats grama and bermudagrass had nearly 100% survival in all highway sites except Nolanville. At the Nolanville site sideoats grama, 'El Reno' had highest survival and bermudagrass the lowest. In general, plant growth was greater in all mycorrhizal colonized grasses (CONTINUED ON BACK OF FORM PAGE)

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at low (1kg/m^3 18N-6P-12) vs. zero fertility levels. At the two Kerrville highway sites mycorrhizal treated green sprangletop, sideoats grama, and bermudagrass produced better stands than nonmycorrhizal plants. An interesting observation was that nonfertilized mycorrhizal grasses had growth comparable to fertilized nonmycorrhizal grasses. Mycorrhizal Chinese tallow (Sapium sebiferum) showed more dramatic growth differences than liveoak (Quercus virginiana). Higher survival occurred with liveoak than with Texas mountain laurel (Sophora secundiflora), and greatest growth occurred with mycorrhizal liveoak at the low fertility level. In greenhouse mycorrhizal studies with grass species, growth increased with increasing fertility levels; mycorrhizal colonized plants had greater growth and mycorrhizal green sprangletop had higher nitrogen uptake than noninoculated controls.

INTERIM REPORT

ENHANCEMENT OF TEXAS HIGHWAYS VEGETATION WITH MYCORRHIZAL FUNGI

by

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Research Report
Research Study 902-3
Roadside Vegetation Management Program

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TEXAS TRANSPORTATION INSTITUTE
The Texas A&M University System
College Station, Texas

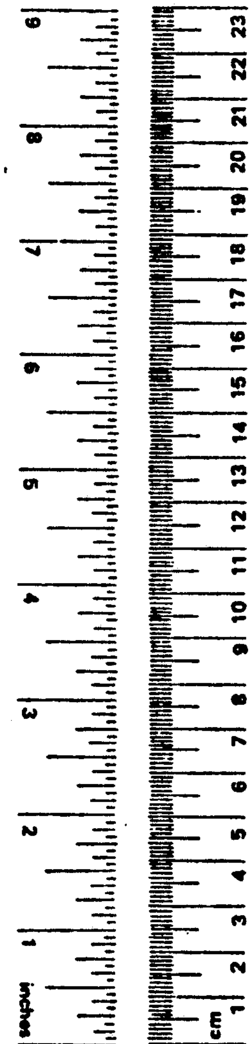
September 1986

METRIC CONVERSION FACTORS

Approximate Conversions to Metric Measures

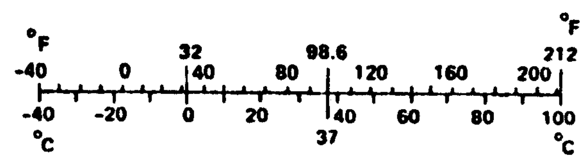
Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
in	inches	*2.5	centimeters	cm
ft	feet	30	centimeters	cm
yd	yards	0.9	meters	m
mi	miles	1.6	kilometers	km
		AREA		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.09	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.6	square kilometers	km^2
	acres	0.4	hectares	ha
		MASS (weight)		
oz	ounces	28	grams	g
lb	pounds	0.45	kilograms	kg
	short tons (2000 lb)	0.9	tonnes	t
		VOLUME		
tsp	teaspoons	5	milliliters	ml
Tbsp	tablespoons	15	milliliters	ml
fl oz	fluid ounces	30	milliliters	ml
c	cups	0.24	liters	l
pt	pints	0.47	liters	l
qt	quarts	0.95	liters	l
gal	gallons	3.8	liters	l
ft^3	cubic feet	0.03	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
		TEMPERATURE (exact)		
°F	Fahrenheit temperature	5/9 (after subtracting 32)	Celsius temperature	°C

*1 in = 2.54 (exactly). For other exact conversions and more detailed tables, see NBS Misc. Publ. 286, Units of Weights and Measures, Price $2.25, SD Catalog No. C13.10:286.



Approximate Conversions from Metric Measures

Symbol	When You Know	Multiply by	To Find	Symbol
		LENGTH		
mm	millimeters	0.04	inches	in
cm	centimeters	0.4	inches	in
m	meters	3.3	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6	miles	mi
		AREA		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.4	square miles	mi^2
ha	hectares (10,000 m^2)	2.5	acres	
		MASS (weight)		
g	grams	0.035	ounces	oz
kg	kilograms	2.2	pounds	lb
t	tonnes (1000 kg)	1.1	short tons	
		VOLUME		
ml	milliliters	0.03	fluid ounces	fl oz
l	liters	2.1	pints	pt
l	liters	1.06	quarts	qt
l	liters	0.26	gallons	gal
m^3	cubic meters	35	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
		TEMPERATURE (exact)		
°C	Celsius temperature	9/5 (then add 32)	Fahrenheit temperature	°F



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Key Words. Erosion Control, Beneficial Soil Fungi, Site Stabilization, Herbaceous and Woody Revegetation Plants.

ABSTRACT

Mycorrhizae are fungi which form beneficial symbiotic associations with roots of a higher plant. Mycorrhizal fungi improve establishment and survival of plants on adverse sites. Construction or reconstruction of a highway produces an environment with tremendous environmental problems for revegetation, which limit plant establishment. An important objective in revegetating highway rights-of-way is establishing a more desirable cover of sod and other plants on roadsides, particularly on cut and fill slopes. Use of mycorrhizal plants is a potential technique for improving the establishment of highway vegetation under difficult Texas environmental conditions with minimal maintenance.

Over the past four years, cooperative research has studied use of mycorrhizal fungi in revegetating Texas highway roadsides near Austin, Winnie, Kerrville, and Nolanville. The study revealed that the two Austin highway sites, the Kerrville site II, and the Nolanville site were difficult to revegetate due to slope, texture of the soil material and their potential for soil erosion. Tests to determine mycorrhizal acitivity were done with bioassays utilizing green sprangletop (Leptochloa dubia), sideoats grama 'El Reno' (Bouteloua curtipendula) and bermudagrass (Cynodon dactylon). Bermudagrass showed the greatest colonization which could be of practical importance in ultimately reducing fertilization practices of bermudagrass stands. Green sprangletop, sideoats, and bermudagrass had nearly 100% survival in all highway sites except Nolanville. In general, plant growth was greater in all mycorrhizal colonized grasses at low (1 kg/m^3 18N-6P-12K) vs. zero fertility levels. At the two Kerrville highway sites mycorrhizal treated green sprangletop, sideoats, and bermudagrass produced better stands than nonmycorrhizal plants. An interesting observation was that nonfertilized mycorrhizal grasses had growth comparable to fertilized nonmycorrhizal grasses. Mycorrhizal Chinese tallow (Sapium sebiferum) showed more dramatic growth differences than liveoak (Quercus virginiana). At the Nolanville site, sideoats 'El Reno' had highest survival and bermudagrass the poorest. Higher survival occurred with liveoak than with Texas mountain laurel (Sophora secundiflora), and greatest growth occurred with mycorrhizal liveoak at the low fertility level. In greenhouse mycorrhizal studies, grass species had increased growth with increasing fertility levels; mycorrhizal colonized plants had greater growth and mycorrhizal green sprangletop had higher nitrogen uptake than noninoculated controls.

SUMMARY

This report describes existing problems in revegetation of Texas highway right-of-way sites, and the advantages of utilizing mycorrhizal fungi systems to enhance revegetation. The report describes research conducted at Texas highway right-of-way sites at Winnie, Austin, Kerrville and Nolanville utilizing beneficial mycorrhizal systems with three herbaceous and three woody revegetation species.

IMPLEMENTATION STATEMENT

This study indicates that there are advantages in utilizing mycorrhizal fungi to enhance revegetation of Texas highway right-of-way sites. On more adverse slopes with both herbaceous and woody plant species, and in the general transplant of woody plant species, mycorrhizal fungi improves plant survival and establishment. Future research should address broadcast use of mycorrhiza during seedage, and seed encapsulation of mycorrhiza.

DISCLAIMER

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CHAPTER I

INTRODUCTION

Construction or reconstruction of a highway produces roadside environments which offer many challenges for revegetation. Revegetating highway roadsides reduces erosion, minizes drainage and water pollution, improves safety and provides a pleasant view to the travelling public.

A variety of native and perennial plants (grasses, legumes, herbaceous flowers, and woody species) are available to achieve these objectives.

Highway Revegetation Problems

An important objective in revegetating Texas highway rights-of-way is establishing more desirable sod cover crops and native plants, particularly on adverse cut and fill slopes. Construction or reconstruction of a highway exposes subsurface layers of soil materials which have no microbes to aid in soil weathering and no beneficial mycorrhizal fungi to enhance plant growth. Consequently, these soil materials are biologically incomplete, even with a surface cover of vegetation. These deficiencies stress plants and limit their growth on the diverse highway sites in Texas because soil moisture is inadequate, soil structure is poor, soil temperatures are abnormally high and fertility is low or marginal.

These problems limit the selection of plant materials capable of surviving and performing well on disturbed sites. New propagation, production, seeding, and transplanting techniques are needed to improve the establishment and survival of a desirable array of plants on highway roadsides.

Use of Mycorrhizal Fungi in Revegetation

Mycorrhizae are beneficial fungi which form symbiotic associations with roots of a higher plants. All potential Texas plants for highway revegetation naturally form beneficial associations with mycorrhizal fungi already in the soil or which are incorporated during seeding or transplanting. Use of mycorrhizal plants accelerates this association and is a potential technique for improving the initial establishment of vegetation under minimal maintenance. This technique will eliminate or reduce the high costs of energy inputs such as fertilizer, water and labor as well as the risk of replanting these adverse sites. It is well documented that mycorrhizal fungi improve plant growth and survival by making the plant more efficient in taking up water and nutrients from the soil, and by improving plant resistance to temperature, water, nutritional and disease stresses (4, 7, 13, 14).

Topsoil materials distributed on highway and strip mine slopes have virtually no viable mycorrhizal spores present (7, 9, 10, 15). However, the potential benefits of utilizing mycorrhizal fungi for revegetating disturbed highway and strip mine soils are known (3, 6, 15).

There are many excellent native Texas herbaceous and woody plants for revegetating highway sites. Plants selected for study and association with mycorrhizal fungi included green sprangletop (*Leptochloa dubia*), sideoats grama 'El Reno' (*Bouteloua curtipendula*), bermudagrass (*Cynodon dactylon*), Texas mountain laurel (*Sophora secundiflora*), liveoak (*Quercus virginiana*), and Texas persimmon (*Diospyros texana*). It is reasonable to believe that incorporating mycorrhizae could improve stands of existing highway vegetation and enhance transplanting and seeding success, and survival of more desirable plant species on sites where these fungi are deficient.

Installing and managing mycorrhizae plants potentially is a low cost method of 1) improving plant stands following revegetation associated with highway construction and reconstruction, 2) improving tolerance of existing highway vegetation to drought and nutritional stresses, and 3) offering landscape architects and vegetation managers a greater diversity of plant materials to install on the Texas highway landscape.

Study Objectives

The primary objectives of this study were: 1) to test effects of mycorrhizal fungi on growth and development of three selected herbaceous plant species under controlled conditions which commonly are planted on roadsides and 2) to test the ability of several herbaceous and woody species colonized with mycorrhizae to establish and develop on roadsides in selected Texas highway Districts.

CHAPTER II

INFLUENCE OF MYCORRHIZAL FUNGI AND TWO FERTILIZER LEVELS ON GROWTH AND DEVELOPMENT OF THREE GLASSHOUSE GROWN REVEGETATION SPECIES

Abstract

Three herbaceous Texas highway revegetation species were grown in standard 12-cm clay containers containing sterilized media individually inoculated with vesicular-arbuscular (VAM) mycorrhizal fungi and fertilized with Osmocote® (18N-6P-12K) at rates Of 0 or 1 kg/m^3. After 150 days, seedlings of green sprangletop inoculated with Glomus mosseae (Nicol. and Gerd.) Gerd. and Trappe and with G. fasciculatus (Thaxt. sensu Gerd.) Gerd. & Trappe had increased shoot fresh and dry weights compared to noninoculated controls. Mycorrhizal sideoats had increased shoot fresh weight at the low fertility level (1 kg/m^3), and at both fertility levels, mycorrhizal plants showed increased fresh and dry weight of roots. Mycorrhizal bermudagrass had increased root fresh weight at both fertility levels and increased root dry weight at the low fertility level. The low fertility regime of 1 kg/m^3 increased both fresh and dry weights of shoots and roots of the three revegetation species. Low fertility levels generally increased nitrogen and potassium contents within the three grass species. Mycorrhizal colonized green sprangletop had increased N uptake at 1 kg/m^3 compared to noncolonized controls. Phosphorus, zinc, iron and magnesium contents were not enhanced by fertilization or by mycorrhizal colonization.

Objectives

Objectives of this research were: 1) to establish mycorrhizal inoculum of selected vesicular-arbuscular mycorrhizal fungi (VAM), and 2) to determine effect of selected mycorrhizal fungi on growth and development of three plant species planted on roadsides in Texas.

Materials and Methods

Inoculum of vesicular-arbuscular mycorrhizal fungi (VAM) Glomus fasciculatus (Thaxt. sensu Gerd.) Gerd. & Trappe and Glomus mosseae (Nicol. & Gerd.) were cultured in containers as previously described by Strong and Davies (12).

Seeds of green sprangletop, sideoats grama 'El Reno' and bermudagrass were surface-sterilized with 10% sodium hypochlorite solution (NaClO) for 10 minutes before sowing. The growing medium was steam-sterilized 1 builders sand (Bryco, College Station, TX) : 1 sandy loam soil (Dothan fine sandy loam) amended with 74 g/m^3 Peters® (W.R. Grace Co.) fritted trace elements and with either 0 or 1.2 kg/m^3 18N-6P-12K Osmocote®, a slow release fertilizer (Sierra Chemical Co.). Before the addition of fertilizer, medium pH was 7.2 with 4 ppm phosphorus.

Standard 12-cm clay containers were filled with medium containing either 100 g of combined Glomus fasciculatus and G. mosseae inoculum or a mycorrhizal-free control. Approximately 0.25 g (450 seeds) of green sprangletop, 0.5 g (175 seeds) of sideoats grama 'El Reno' or 0.25 g (2200 seeds) of bermudagrass were separately sown in containers. A completely randomized design was used consisting of 3 grass species X 2 mycorrhizal levels X 2 fertilizer levels with 10 replications per treatment and 1 container per replication.

Data were recorded 150 days after sowing and included shoot and root fresh and dry weights and shoot/root ratios on a dry weight basis. Total N was determined using a Technicon Autoanalyzer® (16) and P, K, Zn, Fe, Mg were determined in an inductively coupled plasma automatic emission spectrophotometer (ICP).

Results and Discussion

The relatively low rate of fertilizer (1 kg/m^3) increased both fresh and dry weights for shoots and roots of the three grass species (Table II-1). At this rate of fertilizer, mycorrhizal colonized green sprangletop had increased shoot fresh and dry weight compared to non-mycorrhizal controls (Table II-1). Mycorrhizal sideoats had increased shoot fresh weight at 1 kg/m^3, and at both fertility levels mycorrhizal plants had increased root fresh and dry weight (Table II-1). Mycorrhizal bermudagrass had increased root fresh weight at both fertility levels and increased root dry weight at the 1 kg/m^3 fertility level (Table II-1).

Low fertility levels generally increased nitrogen and potassium concentration within the three grass species (Table II-2). Mycorrhizal colonized green sprangletop had increased N uptake at 1 kg/m^3 compared to noncolonized controls. Phosphorus, zinc, iron and magnesium were not enhanced by fertilization or mycorrhizal colonization (Table II-2). It should be noted that tissue analysis of the shoot systems was done during a period of senescence and decline, and there may have been remobilization of elements from the shoot system to other plant organs. Media analysis, before fertilizer was incorporated, indicated high to medium levels of Zn (.38 ppm), Fe (16.1 ppm), and Mg (50 ppm).

CHAPTER III

INFLUENCE OF MYCORRHIZAL FUNGI AND TWO FERTILITY LEVELS ON REVEGETATION SURVIVAL AND GROWTH ON A WINNIE, TX AND TWO AUSTIN HIGHWAY RIGHT-OF-WAY SITES

Abstract

Soil analyses and mycorrhizal bioassays of soil taken from Winnie, TX and two Austin highway right-of-way sites were conducted. Soil taken from the Winnie site was classified as a sandy loam; the salt index and SAR ratios were low with moderate calcium levels. Soil taken from Austin site I was classified as a silt loam. The salt index and SAR ratios were low; however both calcium and magnesium were the highest of the three sites recorded. Soil taken from Austin site II was classified as a loam. The two Austin sites had highly compacted soil, steep slopes, were highly eroded and much steeper (more severe revegetation sites) than the Winnie site.

Mycorrhizal bioassays indicated lowest colonization levels of naturally occurring mycorrhizal fungi on Austin site I which was a highly eroded, newly-formed slope.

For the outplanting portion of this research green sprangletop (Leptochloa dubia), sideoats grama 'El Reno', (Bouteloua curtipendula) and bermudagrass (Cynodon dactylon) were sown in Jiffy® pots and transplanted to the three highway sites five weeks later.

On Austin site I, 100% survival occurred in all treatments, which is indicative of the transplanting benefits of the Jiffy pot system where no root disturbance occurs, minimizing transplant shock. Low fertility compared to zero levels gradually increased plant height, width and the growth index levels. Mycorrhizal green sprangletop had greater height and width at the zero fertility level compared to noncolonized controls. For all growth parameters, mycorrhizal sideoats 'El Reno' had greater growth responses at both fertility levels than noncolonized controls. At the zero fertility level mycorrhizal bermudagrass had greater growth responses than noncolonized controls.

On Austin site II, 100% survival also occurred in all treatments and increased fertility enhanced all growth parameters measured.

Objectives

Objectives of this research were: 1) to determine soil characteristics and mycorrhizal activity of three Texas highway right of way sites and 2) to monitor survival and growth of three herbaceous mycorrhizal revegetation species on the three Texas highway right of way sites.

Materials and Methods

Mycorrhizal bioassays of soil taken from the Winnie, TX and two Austin highway right-of-way sites were conducted with three herbaceous revegetation species: green sprangletop, sideoats grama 'El Reno' and bermudagrass. VAM colonization was determined using the techniques of Phillips and Hayman (8) and Bevage (1). Soil particle size analysis, soil physical measurements and soil salinity analysis of the three highway sites were conducted using standard laboratory procedures (2).

For the outplanting portion of this research, seeds of green sprangletop, sideoats grama 'El Reno' and bermudagrass were surface-sterilized with 10% NaClO for 10 minutes before sowing. The growing medium was steam-sterilized 1 builders sand (Bryco, College Station, TX) : 1 sandy loam soil (Dothan fine sandy loam) amended with 74 g/m^3 Peters® (W.R. Grace Co.) fritted trace elements and either 0 or 1.2 kg/m^3 18N-6P-12K Osmocote®, a slow release fertilizer (Sierra Chemical Co.). Before the addition of fertilizer, medium pH was 7.2 with 4 ppm phosphorus. Biodegradeable #230 Jiffy® pots (Hummert Seed Co.) (7.62 cm x 7.62 cm) were filled with medium containing either 50 g of combined Glomus fasciculatus (Thaxt. sensu Gerd.) Gerd. & Trappe and Glomus mosseae (Nicol. and Gerd.) Gerd. and Trappe inoculum or mycorrhizal-free control; inoculum of these two VAM fungi were cultured in containers as previously described by Strong and Davies (12). Approximately 0.25 g (450 seeds) of green sprangletop, 0.5 g (175 seeds) of sideoats 'El Reno' or 0.25 g (2200 seeds) of bermudagrass were separately sown in Jiffy® pots and grown under glasshouse conditions for five weeks. Plants were then hardened off for two weeks before transplanting to the 3 highway right-of-way sites. At each highway site a completely randomized design was used for planting, and it consisted of 3 grass species x 2 mycorrhizal levels x 2 fertilizer levels with 15 replications per treatment and 1 Jiffy® pot per replication.

Data were recorded 120 days after transplanting and included percentage survival, height, width and a growth index (height x width/2).

Results and Discussion

Soil taken from the Winnie site contained 1% gravel, 26% silt, 18.3% clay and 54.7% total sand (Table III-1). The sand fraction was predominantly fine-very fine textured (Table III-1). This soil would be classified as a sandy loam. It had a bulk density of 1.30 g cm^{-3}, an infiltration rate of less than 0.1 inches of water per hour, and moisture retention of 26.9%, with a pH 7.5 (Table III-2). The salt index and sodium absorption ratio (SAR) were low with moderate calcium levels (Table III-3).

Soil taken from Austin site I contained 5.4% gravel, 51.5% silt, 18.2% clay, and 24.9% total sand (Table III-1). The sand fraction was predominantly fine texured and this soil was classified as a silt loam. It had a bulk density of 1.56 g cm^{-3}, and an infiltration rate of 22.4 inches of water per hour, a moisture retention of 19.1%, and a pH of 7.6 (Table III-2). The salt index and SAR ratios were low; however, calcium and magnesium were the highest of the three sites recorded (Table III-3).

Soil taken from Austin site II contained 4.1% gravel, 46.5% silt, 18.6% clay, and 30.8% total sand (Table III-1). The sand fraction was predominantly fine-medium textured, and this soil was classified as a loam. It had a bulk density of 1.59 g cm^{-3}, an infiltration rate of less than 0.1 inches of water per hour, and a moisture retention of 21.2% and a pH of 7.6 (Table III-2). The salt index, SAR, calcium and magnesium were at acceptable levels for plant growth (Table III-3). It should be noted that the Winnie site was most conducive for revegetation and that native vegetation and Johnson grass competed strongly with the transplanted mycorrhizal plants. The two Austin sites had highly compacted soil, steep slopes, were highly eroded and much more severe revegetation sites.

Mycorrhizal bioassays indicated lowest colonization levels of naturally occurring mycorrhizal fungi on Austin site I (Table III-4) which was a highly eroded fill slope.

On Austin site I, 100% survival occurred in all treatments, which is indicative of the transplanting benefits of the Jiffy® pot system where no root disturbance occurs, minizing transplant shock. Low fertility levels (1 kg/m^3) generally increased plant height, width and the growth index levels (Table III-5). Mycorrhizal green sprangletop had greater height and width at the low fertility level compared to noncolonized controls (Table III-5). At the zero fertility level, mycorrhizal bermudagrass had greater growth responses than noncolonized controls.

On Austin site II, 100% survival also occurred in all treatments, and increased fertility enhanced all growth parameter measured (Table III-6).

CHAPTER IV

INFLUENCE OF MYCORRHIZAL FUNGI AND FERTILITY ON HERBACEOUS AND WOODY SPECIES OUTPLANTED ON TWO KERRVILLE, TX HIGHWAY RIGHT-OF-WAY SITES

Abstract

Soil nutrient characteristics and mycorrhizal activity of two Kerrville, TX highway right-of-way sites were determined, and three herbaceous and two woody mycorrhizal revegetation species were outplanted and monitored for survival and growth.

Both Kerrville highway right-of-way sites had high soil pH and comparable hnutrient levels. Site II was much more severe with a steep slope, high erosion and a southern exposure. Mycorrhizal colonization indicated higher natural colonization rates for Site I.

On both sites, 100% survival occurred with all herbaceous and woody plant revegetation treatments. On site I mycorrhizal sideoats grama and bermudgrass had greater growth responses at both fertility levels compared to noncolonized controls. On the more severe slope II, greater growth responses occurred with all three mycorrhizal grass species, particularly at the 0 kg/m^3 fertility level.

Both woody species had greater growth responses on site II. Mycorrhizal Chinese tallow did better than nonmycorrhizal controls on both sites. With the slower growing liveoaks, there was no difference in mycorrhizal treatments.

Objectives

Objectives of this research were: 1) to determine soil nutrient characteristics and mycorrhizal activity of two Kerrville, TX highway right-of-way sites and 2) to monitor survival and growth of three herbaceous and two woody mycorrhizal revegetation species on the Kerrville sites.

Materials and Methods

Mycorrhizal bioassays of soil taken from the Kerrville, TX highway right-of-way site were conducted with three herbaceous revegetation species: green sprangletop, sideoats grama 'El Reno', and bermudagrass. VAM colonization was determined using the techniques of Phillips and Hayman (8) and Bevage (1).

For the outplanting portion of this research, seeds of green sprangletop, sideoats grama 'El Reno', bermudagrass, liveoak (Quercus virginiana) and Chinese tallow (Sapium sebiferum) were surface sterilized with 10% NaClO for 10 minutes before sowing. The growing medium was steam-sterilized 1 builders sand (Bryco, College Station, TX) : 1 sandy loam soil (Dothan fine sandy loam) amended with 74 g/m^3 Peters® (W.R. Grace Co.) fritted trace elements and either 0 or 1.2 kg/m^3 18N-6P-12K Osmocote®, a slow release fertilizer (Sierra Chemical Co.,). Before the addition of fertilizer, medium pH was 7.2 with 4 ppm phosphorus. For the three herbaceous species biodegradeable #230 Jiffy® pots (Hummert Seed Co.) (7.62 cm x 7.62 cm) were filled with medium containing either 50 g of combined Glomus fasciculatus (Thaxt. sensu Gerd.) Gerd. & Trappe and Glomus mosseae (Nicol. and Gerd.) Gerd. and Trappe inoculum or mycorrhizal-free control; inoculum of these two VAM fungi were cultured in containers as previously described by Strong and Davies (12). Approximately 0.25 g (450 seeds) of green sprangletop, 0.5 g (175 seeds) of sideoats grama 'El Reno' or 0.25 g (2200 seeds) of bermudagrass were separately sown in Jiffy® pots and grown under glasshouse conditions for five weeks.

For the two woody species, Spenser Lemaire booklet seedling trays (Edmonton, Canada) were used instead of the smaller volumed Jiffy® pots. Mycorrhizal Chinese tallow seedlings were treated with the same VAM as herbaceous material; however, mycorrhizal liveoak seedlings were colonized with the ectomycorrhizal fungi, Pisolithus tinctorius following the procedures of Marx, et al. (6, 11). All woody species were sown in media containing 1 kg/m^3 18N-6P-12K Osmocote.

Plants were then hardened off for two weeks before transplanting to the two highway right-of-way sites. At each highway site a completely randomized design was used consisting of 3 grass species x 2 mycorrhizal levels x 2 fertilizer levels with 10 replications per treatment and 1 Jiffy® pot per replication. For the woody revegetation species a completely randomized design was used consisting of 2 woody species x 2 mycorrhizal levels with 20 replications per treatment and one seedling transplant per replication.

Data were recorded 150 days after transplanting and included percentage survival, height, and width.

Results and Discussion

Both Kerrville highway right of way sites had high soil pH and comparable nutrient levels (Table IV-1). Site II was a much more severe site having a steep slope and a southern exposure. Mycorrhizal colonization indicated higher natural colonization rates for Site I with the three grass species used for bioassays (Table IV-2).

On both sites, 100% survival occurred with all herbaceous and woody transplants (Table IV-3, IV-4, IV-5). On site I mycorrhizal sideoats grama and bermudagrass had greater growth responses at both fertility levels compared to noncolonized controls (Table IV-3). On the more severe slope II, greater growth responses occurred with all three mycorrhizal grass species, particularly at the 0 kg/m^3 fertility level (Table IV-4).

Both woody species had greater growth responses on Site II (Table IV-5). Most likely this was due to less competition from competing natural vegetation and johnsongrass found on Site I. Mycorrhizal Chinese tallow did better than nonmycorrhizal controls in both sites. The slower growing liveoaks, showed no differences in growth due to mycorrhizal treatment (Table IV-5).

CHAPTER V

INFLUENCE OF MYCORRHIZAL FUNGI AND FERTILITY ON HERBACEOUS AND WOODY SPECIES OUTPLANTED ON A NOLANVILLE, TX HIGHWAY RIGHT-OF-WAY SITE

Abstract

Soil nutrient and salinity characteristics and survival and growth of three herbaceous and two woody mycorrhizal revegetation species were determined on a Nolanville, TX highway right-of-way site.

Soil pH was alkaline; however, low phosphorus and moderate salinity were conducive to mycorrhizal seedling establishment. This site had a steep slope and was highly eroded.

Survival of the three herbaceous species transplanted ranged from 47-100%. Sideoats grama 'El Reno' had highest survival and bermudagrass had the lowest.

Higher survival occurred with liveoak than with Texas mountain laurel. Highest survival and growth occurred with mycorrhizal liveoak at the low (1 kg/m^3) fertility level.

Objectives

Objectives of this research were: 1) to determine soil nutrient and salinity characteristics of a Nolanville, TX highway right-of-way site and 2) to monitor survival and growth of three herbaceous and two woody mycorrhizal revegetation species on the Nolanville site.

Materials and Methods

For the outplanting portion of this research, seeds of green sprangletop, sideoats grama 'El Reno', bermudagrass, liveoak and Texas mountain laurel (*Sophora secundiflora*) were surface sterilized with 10% NaClO for 10 minutes before sowing. The growing medium was steam-sterilized 1 builders sand (Bryco, College Station, TX) : 1 sandy loam soil (Dothan fine sandy loam) amended with 74 g/m^3 Peters® (W.R. Grace Co.) fritted trace elements and either 0 or 1.2 kg/m^3 18N-6P-12K Osmocote®, a slow release fertilizer (Sierra Chemical Co.,). Before the addition of fertilizer, medium pH was 7.2 with 4 ppm phosphorus. For the three herbaceous species biodegradeable #230 Jiffy® pots (Hummert Seed Co.) (7.62 cm x 7.62 cm) were filled with medium containing either 50 g of combined *Glomus fasciculatus* (Thaxt. sensu Gerd.) Gerd. & Trappe and *Glomus mosseae* (Nicol. and Gerd.) Gerd. and Trappe inoculum or mycorrhizal-free control; inoculum of these two VAM fungi were cultured in containers as previously described by Strong and Davies (12). Approximately 0.25 g (450 seeds) of green sprangletop, 0.5 g (175 seeds) of sideoats grama 'El Reno' or 0.25 g (2200 seeds) of bermudagrass were separately sown in Jiffy® pots and grown under glasshouse conditions for five weeks. Procedures for outplanting were described in Chapter IV, and there were 20 replications per treatment and one Jiffy® pot per replication.

For the two woody species, Spenser Lemaire booklet seedling trays

(Edmonton, Canada) were used instead of the smaller Jiffy® pots. Mycorrhizal Texas mountain laurel seedlings were treated with the same VAM as herbaceous material; however, mycorrhizal liveoak seedlings were colonized with the ectomycorrhizal fungi, *Pisolithus tinctorius* following the procedures of Marx, et al. (6, 11). All woody species were sown in media containing 1 kg/m^3 18N-6P-12K Osmocote. There were 20 replications per treatment and one seedling per replication.

Data were recorded 386 days after transplanting and included percentage survival, height, and diameter (caliper).

Results and Discussion

Soil pH was alkaline, however, low phosphorus and moderate salinity were conducive to mycorrhizal seedling establishment (Table V-1). This was a steep slope and highly eroded.

Survival of the 3 herbaceous species transplanted on the Nolanville site ranged from 47-100% (Table V-2). Sideoats grama 'El Reno' had the best survival and bermudagrass had the poorest. Again, there was severe erosion on the site which eliminated some plantings.

Higher survival occurred with liveoak than with Texas mountain laurel (Table V-3). Highest survival and growth occurred with fertilized mycorrhizal liveoak (Table V-3).

Conclusions

Three herbaceous Texas highway revegetation species were grown in 12 cm standard clay containers filled with sterilized media. Pots were individually inoculated with vesicular-arbuscular (VAM) mycorrhizal fungi and fertilized with Osmocote (18N-6P-12K) at rates of 0 or 1 kg/m^3. After 150 days, seedlings of green sprangletop inoculated with Glomus mosseae (Nicol. & Gerd.) Gerd & Trappe and with G. fasciculatus (Thaxt. sensu Gerd.) Gerd & Trappe had increased shoot fresh and dry weights compared to nonmycorrhizal controls. Mycorrhizal sideoats grama had increased shoot fresh weight at the low fertility level (1 kg/m^3), and mycorrhizal plants had increased root fresh and dry weight at both fertility levels of roots. Mycorrhizal bermudagrass had increased root fresh weight at both fertility levels and increased root dry weight at the low fertility level. The fertility regime of 1 kg/m^3 increased shoot and root fresh and dry weight of the three grass species. Low compared to zero fertility levels genrally increased nitrogen and potassium contents of the three grass species. Mycorrhizal colonized green sprangletop had increased N uptake at 1 kg/m^3 compared to nonmycorrhizal controls. Phosphorus, zinc, iron and magnesium were not enhanced by fertilization or mycorrhizal colonization.

Soil analyses and mycorrhizal bioassays of soil taken from Winnie, TX and two Austin highway right-of-way sites were conducted. Soil taken from the Winnie site was classified as a sandy loam; the salt index and SAR ratios were low with moderate calcium levels. Soil taken from Austin site I was classified as a silt loam. The salt index and SAR ratios were low; however, both calcium and magnesium were the highest of the three sites recorded. Soil taken from Austin site II was classified as a loam. The two Austin sites had highly compacted soil, steep slopes, were highly eroded and had much more severe revegetation sites than the Winnie site.

Mycorrhizal bioassays indicated lowest colonization levels of naturally occurring mycorrhizal fungi on Austin site I which was a highly eroded, newly formed slope.

For the outplanting portion of this research, green sprangletop, sideoats 'El Reno', and bermudagrass were sown in Jiffy pots and transplanted to the three highway sites.

On Austin site I, 100% survival occurred in all treatments, which is indicative of the transplanting benefits of the Jiffy pot system where no root disturnbance occurs, minimizing transplant shock. Fertilizer (1 kg/m^3) generally increased plant height, width and growth index levels. Mycorrhizal green sprangletop had greater height and width at the zero fertility level compared to noncolonized controls. For all growth parameters, mycorrhizal sideoats grama 'El Reno' had greater growth responses at both fertility levels than noncolonized controls. At the zero fertility level mycorrhizal bermudagrass grew better than noncolonized controls.

On Austin site II, 100% survival also occurred in all treatments and increased fertilty enhanced all growth parameters measured.

Soil nutrient characteristics and mycorrhizal activity of two Kerrville, TX highway right-of-way sites were determined, and three herbaceous and two woody mycorrhizal revegetation species were outplanted and monitored for survival and growth.

Both Kerrville highway right of way sites had high soil pH and comparable nutrient levels. Site II was much more severe with a steep slope, highly eroded and had a southern exposure. Mycorrhizal colonization indicated higher natural colonization rates for site I.

On both sites, 100% survival occurred with all herbaceous and woody plant revegetation treatments. On site I, mycorrhizal sideoats grama and bermudagrass had greater growth responses at both fertility levels compared to noncolonized controls. On the more severe slope II, greater growth responses occurred with all three mycorrhizal grass species, particularly at the 0 kg/m^3 fertility level.

Both woody species had greater growth responses on site II. Mycorrhizal Chinese tallow did better than nonmycorrhizal controls in both sites. With the slower growing liveoaks, there was no difference in mycorrhizal treatments.

Soil nutrient and salinity characteristics and survival and growth of three herbaceous and two woody mycorrhizal revegetation species were determined on a Nolanville, TX highway right-of-way site.

Soil pH was alkaline; however, low phosphorus and moderate salinity were conducive to mycorrhizal seedling establishment. This site had a severe slope and was highly eroded.

Survival of the 3 herbaceous species transplanted ranged from 47-100%. Sideoats grama 'El Reno' had best survival and bermudagrass had the poorest.

Higher survival occurred with liveoak than Texas mountain laurel. Highest survival and growth occurred with mycorrhizal liveoak at the low (1 kg/m^3) fertility level.

Table II-1. Influence of mycorrhizal fungi and fertilizer on growth of three grass species grown in a greenhouse.

Grass Species	Mycorrhizal Inoculated	Fertilization	Shoot Fresh WGT (g)	Shoot Dry WGT (g)	Root Fresh WGT (g)	Root Dry WGT (g)	Shoot/Root Ratio Dry WGT
Green Sprangletop	No	$0kg/m^3$ [z]	29.5c	16.8c	33.8b	16.5b	1.0
		$1kg/m^3$	74.4b	36.4b	94.9a	30.2a	1.2
	Yes	$0kg/m^3$	29.8c	18.7c	39.4b	17.5b	1.1
		$1kg/m^3$	89.1a	42.9a	97.8a	31.0a	1.4
Sideoats 'El Reno'	No	$0kg/m^3$	22.1c	15.5b	46.5c	26.8c	0.6
		$1kg/m^3$	43.5b	27.2a	87.6b	41.4b	0.7
	Yes	$0kg/m^3$	31.7c	20.2b	76.4b	40.5b	0.5
		$1kg/m^3$	56.6a	30.2a	124.3a	56.3a	0.5
Bermudgrass	No	$0kg/m^3$	22.3c	15.7b	24.4d	14.1b	1.1
		$1kg/m^3$	69.1ab	38.8a	68.4b	24.8b	1.6
	Yes	$0kg/m^3$	29.4c	19.9b	44.4c	21.7b	0.9
		$1kg/m^3$	77.6a	40.5a	110.1a	45.4a	0.9

[z] Mean separation within columns by Duncan's multiple range test, 5% level.

Table II-2. Influence of mycorrhizal fungi and fertilizer on growth of three grass species grown in a greenhouse.

Grass Species	Mycorrhizal	Fertilization	%N	%P	%K	%Zn	%Fe	%Mg
Green Sprangletop	No	0kg/m^3 [z]	0.60c	0.11a	0.40b	0.03a	0.03	0.13a
		1kg/m^3	0.73b	0.10a	0.61a	0.02a	0.01a	0.11a
	Yes	0kg/m^3	0.48c	0.09a	0.49ab	0.03a	0.02a	0.12a
		1kg/m^3	0.89a	0.10a	0.59a	0.02a	0.01a	0.10a
Sideoats	No	0kg/m^3	0.49b	0.09a	0.33b	0.02a	0.03a	0.08a
		1kg/m^3	0.86a	0.09a	0.53a	0.02a	0.01b	0.09a
	Yes	0kg/m^3	0.61b	0.08a	0.32b	0.02a	0.02a	0.08a
		1kg/m^3	0.98a	0.08a	0.62a	0.02a	0.02a	0.08a
Bermudgrass	No	0kg/m^3	0.48b	0.08a	0.52a	0.03a	0.06a	0.10a
		1kg/m^3	0.70a	0.13a	0.50a	0.02a	0.01b	0.10a
	Yes	0kg/m^3	0.44b	0.11a	0.40a	0.02a	0.03b	0.07a
		1kg/m^3	0.59ab	0.08a	0.43a	0.02a	0.02b	0.09a

[z] Mean separation within columns by Duncan's multiple range test, 5% level.

Table III-1. Soil particle size analysis of three Texas highway revegetation sites.

					Sand Fractions				
Site	Gravel 2mm (9 mesh) %	Sand (9.300) mesh %	Silt .002-15mm (300) mesh %	Clay .002-05mm %	Very Coarse 1-2 mm (9-16) mesh %	Coarse 0.5-1mm (16-32) mesh %	Medium 0.25-5mm (32-60) mesh %	Fine 0.1-25mm (60-140) mesh %	Very Fine 0.05-1mm (140-300) mesh %
Winnie	1.0	54.7	26	18.3	0.5	0.5	0.9	28.3	24.5
Austin I	5.4	24.9	51.5	18.2	2.4	5.7	3.4	9.8	3.6
Austin II	4.1	30.8	46.5	18.6	3.1	5.7	8.5	8.9	4.6

Table III-2. Soil physical measurement of three Texas highway revegation sites.

Site	Bulk Density g/cm	% Pore Space		Infiltration rate-inches of H_2O/Hour	Percent Moisture Retention at Pressure Indicated	pH of Mixture
		Capil-ary	Non Capil-ary		40 cm of H_2O	
Winnie	1.30	34.8	16.2	0.1	26.9	7.5
Austin I	1.56	29.9	11.1	22.4	19.1	7.6
Austin II	1.59	33.8	6.0	0.1	21.2	7.6

Table III-3. Soil salinity analysis of three Texas highway revegetation sites.

Site Location	Salt Index	S.A.R.	Cations: Calcium e.p.m.	Calcium p.p.m.	Magnesium e.p.m.	Magnesium p.p.m.	Sodium e.p.m.	Sodium p.p.m.
Winnie	1.2	.30	12.19	234.8	2.4	29.3	.80	18.4
Austin I	2.1	.27	17.73	354.6	9.88	120.5	1.00	23.0
Austin II	1.4	1.67	10.17	203.4	4.39	53.6	4.50	103.5

Table III-4. Mycorrhizal infectivity of soil samples taken from three highway revegetation sites. Three grass species were used as bioassays and mycorrhizal infection measured after four weeks of pot culture.

Site	Green Sprangletop	Sideoats 'El Reno'	Bermuda Grass
Winnie	0%[z]	50%	100%
Austin I	25%	0%	25%
Austin II	50%	25%	100%

[z] Based on percentage of roots colonized by mycorrhizal fungi vesicles, mycelium and spores.

Table III-5. Austin highway site I. Effect of mycorrhizal fungi and two fertilizer levels on survival and growth of three transplanted grass species. Plants were transplanted on 5-27-82 and evaluated on 8-19-82.

Grass Species	Mycorrhiza Colonized	Fertilization	Survival	Height (cm)	Width (cm)	(Height + Width)/2
Green Sprangletop	No	0kg/m^3 [z]	100%a	13.6b	7.2c	10.4b
		1kg/m^3	100%a	20.0a	11.6b	15.8a
	Yes	0kg/m^3	100%a	20.4a	15.8a	18.1a
		1kg/m^3	100%a	20.8a	15.8a	18.3a
Sideoats 'El Reno'	No	0kg/m^3	100%a	8.4c	7.2c	7.8c
		1kg/m^3	80%a	11.0b	10.6b	10.8b
	Yes	0kg/m^3	100%a	11.6b	11.2b	11.4b
		1kg/m^3	100%a	17.2a	16.4a	16.8a
Bermudagrass	No	0kg/m^3	100%a	7.8c	9.8c	8.8c
		1kg/m^3	100%a	16.2a	21.4a	18.8a
	Yes	0kg/m^3	100%a	9.8b	13.2b	11.5b
		1kg/m^3	100%a	16.4a	18.0a	17.2a

[z] Mean separation within columns by Duncan's multiple range test, 5% level.

Table III-6. Austin highway site II. Effect of mycorrhizal fungi and two fertilizer levels on survival and growth of three transplanted grass species. Plants were transplanted on 5-27-82 and evaluated on 8-19-82.

Grass Species	Mycorrhizal Colonized	Fertilization	Survival	Height (cm)	Width (cm)	(Height + Width)/2
Green Sprangle Top	No	0kg/m^3[z]	100%	13.2b	9.6b	11.4b
		1kg/m^3	100%	17.2a	13.2a	15.2a
	Yes	0kg/m^3	100%	14.2b	11.0ab	12.6b
		1kg/m^3	100%	21.4a	14.8a	18.1a
Side Oats 'El Reno'	No	0kg/m^3	100%a	9.2b	7.0b	8.1b
		1kg/m^3	100%a	15.0a	12.0a	13.5a
	Yes	0kg/m^3	100%a	11.8ab	11.2a	11.5a
		1kg/m^3	100%a	13.8a	10.0a	11.9a
Bermuda Grass	No	0kg/m^3	100%a	12.2b	11.4b	11.8b
		1kg/m^3	100%a	17.4a	16.8a	17.1a
	Yes	0kg/m^3	100%a	13.0b	11.4b	12.2b
		1kg/m^3	100%a	16.2a	17.0a	16.6a

[z] Mean separation within columns by Duncan's multiple rante test, 5% level.

Table IV-1. Soil pH and nutritional analysis of two highway revegetation sites in Kerrville, TX.

Sample	pH	Nitrogen (ppm)	Phosphorous (ppm)	Potassium (ppm)	Calcium (ppm)	Magnesium (ppm)	Zinc (ppm)	Iron (ppm)	Maganese (ppm)
Site I	8.1	<1	<5	594	>4000	418	0.22	15.8	10
Site II	8.5	<1	12	342	>4000	>500	0.13	8.4	6.4

Table IV-2. Mycorrhizal infectivity of soil samples taken from two highway revegetation sites at Kerrville, Texas. Three grass species were used as bioassays and mycorrhizal colonization measured after four weeks of pot culture.

Site	Green sprangletop	Sideoats	Bermudagrass
Site 1	30%[z]	50%	90%
Site 2	25%	10%	25%

[z] Based on percentage of roots colonized by mycorrhizal fungi vesicles, myceluim and spores.

Table IV-3. Influence of mycorrhizal fungi and two fertilizer levels on growth and survival of three highway herbaceous revegetation species. Kerrville, Texas, Site I, 1983.

Revegetation Species	Mycorrhizal Colonized	Fertilization	% Survival	Avg. Hgt. (cm)	Avg. Width (cm)
Green Sprangletop *Leptochloa dubia*	No	$0 kg/m^3$	100%a[z]	38.3b	7.9b
		$1 kg/m^3$	100%a	50.1a	8.9a
	Yes	$0 kg/m^3$	100%a	36.6b	9.4a
		$0 kg/m^3$	100%a	42.3b	9.8a
Sideoats 'El Reno' *Bouteloua curtipendula*	No	$0 kg/m^3$	100%a	22.9c	7.4b
		$1 kg/m^3$	100%a	34.2b	8.0b
	Yes	$0 kg/m^3$	100%a	34.3b	9.6a
		$1 kg/m^3$	100%a	45.71	0.3a
Bermudagrass *Cynodon dactylon*	No	$0 kg/m^3$	100%a	19.7b	7.7b
		$1 kg/m^3$	100%a	23.3b	8.3b
	Yes	$0 kg/m^3$	100%a	23.0b	9.4a
		$1 kg/m^3$	100%a	29.6a	9.1a

[z] Mean separation within columns by Duncan's multiple range test, 5% level.

Table IV-4. Influence of mycorrhizal fungi and two fertilizer levels on growth and survival of three highway revegetation species. Kerrville, Texas, Site II, 1983.

Revegetation Species	Mycorrhizal	Fertilization	% Survival	Avg. Hgt. (cm)	Avg. Width (cm)
Green Sprangletop *Leptochloa dubia*	No	$0kg/m^3$	100%a[z]	14.1b	6.0b
		$1kg/m^3$	100%a	28.9a	10.1a
	Yes	$0kg/m^3$	100%a	32.4a	10.7a
		$1kg/m^3$	100%a	34.5a	11.3a
Side Oats 'El Reno' *Bouteloua curtipendula*	No	$0kg/m^3$	100%a	13.4c	7.3c
		$1kg/m^3$	100%a	27.0b	11.5b
	Yes	$0kg/m^3$	100%a	38.1a	14.0a
		$1kg/m^3$	100%a	29.3b	12.0b
Bermuda Grass *Cynodon dactylon*	No	$0kg/m^3$	100%a	9.2b	8.8c
		$1kg/m^3$	100%a	22.1a	15.7a
	Yes	$0kg/m^3$	100%a	18.0a	11.7b
		$1kg/m^3$	100%a	21.6a	14.1a

[z] Mean separation within columns by Duncan's multiple range test, 5% level.

Table IV-5. Influence of mycorrhizal fungi on survival and growth of two woody revegetation species. Kerrville, Texas, Sites I & II, 1983.

Revegetation Species	Site Location	Mycorrhizal	Colonized	% Survival	Avg. Hgt.
Live oak					
Quercus virginiana	Site I		No	100%a[z]	14.4b
			Yes	100%a	16.7b
	Site II		No	100%a	21.0a
			Yes	100%a	28.2a
Chinese Tallow					
Sapium sebiferum	Site I		No	100%a	34.2c
			Yes	100%a	47.9b
	Site II		No	100%a	46.5b
			Yes	100%a	55.8a

[z] Mean separation within columns by Duncan's multiple range test, 5% level.

Table V-1. Soil analysis of a Nolanville highway revegetation site.

	SOIL TEST RATINGS (parts per million)[z]		
PH.........8.3	MODERATELY ALKALINE	MAGNESIUM...426	HIGH
NITROGEN...5	VERY LOW	IRON 2.1	LOW
PHOSPHOUS..1	VERY LOW	ZINC........0.17	LOW
POTASSIUM..156	HIGH	MANGANESE...0.8	LOW
CALCIUM....3521	VERY HIGH	SODIUM......605	MODERATE
		SALINITY....251	(EC=.4)

[z] PPM x 2 = LBS/ACRE 6 INCHES DEEP

Table V-2. Influence of mycorrhizal fungi and two rates of fertilizer on growth and survival of highway revegetation species. Nolanville, TX. Field study was initiated 5-10-84 and evaluated 6-14-85.

Revegetation Species	Mycorrhizal Inoculated	Fertilization	% Survival	Avg. Hgt. (cm)	Avg. Width (cm)
Green Sprangletop *Leptochloa dubia*	No	$0 kg/m^3$	60%b[z]	28.5a	9.4a
		$1 kg/m^3$	80%ab	28.4a	11.1a
	Yes	$0 kg/m^3$	100%a	37.9a	11.5a
		$1 kg/m^3$	93%a	28.4a	11.6a
Sideoats 'El Reno' *Bouteloua curtipendula*	No	$0 kg/m^3$	87%a	26.9a	12.7a
		$1 kg/m^3$	80%a	28.2a	12.5a
	Yes	$0 kg/m^3$	93%a	25.4a	13.6a
		$1 kg/m^3$	87%a	34.6a	15.2a
Bermuda grass *Cynodon dactylon*	No	$0 kg/m^3$	47%a	12.3a	5.3b
		$1 kg/m^3$	53%a	11.6a	7.8a
	Yes	$0 kg/m^3$	47%a	13.2a	8.8a
		$1 kg/m^3$	47%a	15.7a	11.7a

[z] Mean separation within columns by Duncan's multiple range test, 5% level.

Table V-3. Influence of mycorrhizal fungi on survival and growth of two woody revegetation species. Nolanville, TX. Field study was initiated 5-10-84 and evaluated 6-14-85.

Revegetation Species	Mycorrhizal Inoculated	Fertilization	% Survival	Avg. Hgt. (cm)	Avg. Caliper (cm)
Texas Mountain Laurel *Sophora secundiflora*	No	1kg/m^3	60%a[z]	12.0a	4.8b
	Yes	1kg/m^3	70%a	17.8a	7.5a
Live oak *Quercus virginiana*	No	0kg/m^3	80%a	29.8b	5.6b
		1kg/m^3	80%a	36.5b	6.6b
	Yes	0kg/m^3	80%a	36.9b	7.4ab
		1kg/m^3	100%a	42.8a	9.1a

[z] Mean separation within columns by Duncan's multiple range test, 5% level.

APPENDIX A

SOIL ANALYSIS OF A FT WORTH, TEXAS RIGHT OF WAY SITE.

Table A-1. Soil analysis of sludge ammendment sampled from Ft. Worth highway site on February 24, 1983.

SOIL TEST RATINGS (parts per million)[z]					
PH	7.3	MILDLY ALKALINE	MAGNESIUM	500	HIGH
NITROGEN	0	PREDICTED RELEASE LOW	IRON . . .	20	HIGH
PHOSPHORUS . .	<150	VERY HIGH	ZINC . . .	2	HIGH
CALCIUM . . .	4000	VERY HIGH	COPPER . . .		

[z] (PPM X 2 = LBS/ACRE 6 INCHES DEEP)

APPENDIX B

GERMINATION AND SURVIVAL OF NATIVE WOODY REVEGETATION SPECIES FOR TEXAS HIGHWAY RIGHT OF WAY SITES.

Table B-1. Germination and survival of glasshouse propagated woody revegetation species evaluated on August 16, 1985.

		Number of Surviving Seedlings
I. Planted 4/18/85		
a) *Quercus macrocarpa* 'Christoval'	with mycorrhiza	24
	no mycorrhiza	16
b) *Juglans microcarpa*	with mycorrhiza	2
	no mycorrhiza	1
c) *Sophora affinis*		40
II. Planted 6/26/85		
a) *Quercus macrocarpa* 'Christoval'		38
b) *Juglans microcarpa*		18

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