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16. Abstract

Individual plantings were installed in each of four operational Districts of TxDOT representative of East, Central, and West, Texas in April 1989. Site preparation consisted of necessary smoothing followed by scarification to a depth of 10 to 13 cm (4.0 to 5.2 in). A standard seeding mixture was installed comparing drilling and hydroseeding. After the seed mixtures were in place, a straw/hay surface mulch with tackifer was placed over the designated seeded area using a mulch blower.

Seeding emergence was good at Coleman, Lufkin, and Tulia, reflecting favorable moisture conditions; emergrnce at Odessa, where rainfall was scant, was marginal. Above-average rainfall the year following planting encouraged the influx of volunteer plants, but seeded stands were not enhanced.

Green sprangletop, sideoats grama, and common bermuda grass (where it was seeded) were most aggressive in early establishment. Indian grass, buffalo grass, blue grama, switchgrass, and little bluestrem increased in frequency within the planted stand over time.

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ESTABLISHMENT OF GRASS MIXTURES ON ROADSIDES

by

Cynthia Lynne Simpkins
Texas Transportation Institute

Research Study Number 7-902
Research Report 902-6
Research Study Title: Roadside Vegetation Management Research Program

Sponsored by the
Texas Department of Transportation

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TEXAS TRANSPORTATION INSTITUTE
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IMPLEMENTATION STATEMENT

The findings reported here are offered for the guidance of Landscape Architects, Vegetation Managers, and others who prepare seed mixtures and other specifications for erosion control on roadsides.

DISCLAIMER

The comments published in this report do not necessarily reflect the official views or concerns of TxDOT, and do not constitute a standard, specification, or regulation. Further, this report is not intended for construction, bidding, or permit purposes. The author is responsible for the accuracy of data in this report.

ACKNOWLEDGMENT

The author is extremely grateful to the Texas Department of Transportation for providing funding to conduct this study. The findings reported here were the basis for a thesis used in partial fulfillment for a Master of Science degree at Texas A&M University.

The assistance of maintenance personnel in TxDOT Districts 5, 6, 11, and 23 in implementing each of the field seeding tests is also gratefully acknowledged.

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SUMMARY

Test seedings were installed in each of four Districts within TxDOT in April 1989 to evaluate the validity of revised specifications. Two locations, Odessa and Tulia, are in the High Plains, Coleman is in the Rolling Plains, and Lufkin is in the Piney Woods.

Each test was organized in the field as a split plot 2 X 2 factorial having four replications. The main plots were mulch and method seeding, and time of observation was the split. An individual analysis was done for each location; locations were not an additional factor. Data was analyzed by ANOVA, and differences were determined using the F statistic at alpha = 0.05 level and Duncan's mean separation.

The grass species designated for each location came up to good stands, except Odessa where rainfall was scant. Green sprangletop, sideoats grama, and common bermudagrass (where it was seeded) were aggressive in early establishment. Green sprangletop remained as a stand component for several years in central and western Texas, but behaves almost as an annual in eastern Texas. Other stand components such as indiangrass, buffalograss, switchgrass, little bluestem, and blue grama increased in frequency over time.

In practice, drill seeding is preferred on slopes 5:1 or flatter; since drills will not track on steeper slopes, hydroseeding is the method of choice on these slopes. While drilling is considered to place seed in close contact with soil, the water stream in hydroseeding has been observed to perform a covering action. Drilling yielded better stands in two of the four locations, probably because less seed washed from the planted area.

A surface mulch moderates the microclimate in the vicinity of individual seeds and protects against erosion from sheet (but not concentrated) flow. Precipitation during the first two months post-seeding was 9.2 in, 9.6 in, and 21.2 in at Tulia, Coleman, and Lufkin, respectively. Considering these amounts of moisture it is not surprising that mulching failed to generate a stand response. High winds blew away some of the mulch at Odessa, leaving much of the test area bare.

In summary, the present specifications for erosion control appear sound and should be retained.

INTRODUCTION

Throughout Texas, cut and fill slopes and other bare areas along rights-of-way present a problem for vegetation establishment. The Texas Department of Transportation (Tx DOT) utilizes standard specifications (20) as guides to revegetate these areas of bare soil on roadsides and medians. Sub-surface soil materials exposed by construction, reconstruction, or maintenance are subject to surface runoff, which transports a sediment load dependent on slope and soil material involved. These subsoil materials may be less fertile, contain little organic matter, and exhibit less structure than their surface counterparts. Technology based on research by Texas Transportation Institute (TTI) has shown that erosion control is a 3-stage operation: (1) site preparation, which may include placement of topsoil, (2) selection and planting of desired vegetative species, and (3) installation of surface mulch (11).

Scheduling of planting operations is an essential part of highway engineering design and construction. Planning is necessary to effectively use the landscape along virtually all highways. Former President Johnson emphasized the need for protecting and enhancing the `quality' values of highway environments in his Conservation Message on Natural Beauty, sent to the Congress on February 8, 1965, in which he said:

> I hope that, at all levels of government, our planners and builders will remember that highway beautification is more than a matter of planting trees or setting aside scenic areas. The roads themselves must reflect, in location and design, increased respect for the natural and social integrity and unity of the landscape and communities through which they pass.

Such 'greenbelts' of open space near cities often are the only natural features in the urban area (5). The roadside offers a pathway for the establishment of new species into an area by spreading seeds brought in by vehicles, animals and other vectors.

Two common methods of seeding rights-of-way are drilling and broadcasting. Hydroseeding is a method of broadcasting in which seeds and other materials are suspended in water and delivered to the area to be planted in a liquid stream. In this report, hydroseeding is the method of choice for broadcasting. These two seeding methods were compared for their capabilities of producing a plant stand to controlling erosion on highway slopes. The "Complete Highway" does not become a reality until all soil areas are stabilized and protected.

This thesis describes a study on establishing a vegetative cover of prescribed plant species within a variety of slopes and growing conditions in the following locations: (1) Tulia and (2) Odessa in the High Plains, (3) Lufkin in the Piney Woods, and (4) Coleman in the Rolling Plains, in TxDOT districts 5, 6, 11 and 23, respectively.

Objectives

The general objectives of this study were (1) to stabilize areas of bare soil; (2) to mitigate the quantity of sediment carried in runoff into streams, lakes, wetlands, and onto the highways; and (3) to improve the visual resources of the roadside landscape.

The specific objectives of this study were:

1. To compare the relative plant establishment achieved with broadcast (hydroseed) and drill seed placement, and
2. To evaluate mulching effectiveness on plant establishment.

LITERATURE REVIEW

The use of grasses and wildflowers on roadsides is not new in Texas. Since the 1920's, Texas has been experimenting with the establishment of vegetation along highways. Nebraska and other states have planted native grasses and wildflowers to control erosion for several decades (5). William Pape, a maintenance foreman for the Texas highway department, was credited with scattering the first wildflower seeds on the highway roadside as early as 1924. A Texas highway commissioner Judge W.R. Ely, recognized that roadways are never built on natural ground but on either cuts or fills. He suggested that roadsides should be landscaped, with construction planned to retain natural beauty. In 1934, the Texas Highway Department began to delay all mowing except for safety purposes until the spring and early summer wildflower plants had gone to seed. This allowed more vegetation to become established (15).

Construction of a highway exposes subsurface layers of soil which are free of plant life and subject to erosion. Completion of construction does not always coincide with an optimum seeding season. Early mitigation of erosion is a desirable practice. Unfortunately, planting for erosion control usually is a last action in completing a project. Therefore, rapid plant establishment greatly reduces soil erosion.

Other factors limiting desirable vegetative growth on highway slope sites in Texas are orientation of the slope to the south or west, inadequate soil moisture, compacted soil, poor physical soil structure, abnormally high soil temperature, and insufficient fertility(23). A visual variety of plants reduces the monotony of high-speed driving (7). Roadside turf also contributes to safety by allowing vehicles space to leave the paved surface and re-enter in a controlled fashion (3).

Plantings along highways are no better than the plants used and the methods employed to plant them (7). Grass mixtures, some containing forbs, control erosion on Texas roadsides. Plants for seeding or sodding are either annual or perennial grasses, perhaps with legumes included. Annual grasses such as oats or barley are used for temporary plantings when the need for cover arises outside the time period that perennial grasses can be planted. A single species is commonly used for temporary seedings, but permanent seedings usually contain mixtures of 4-6 species.

The choice of species for permanent seedings should consider the ease and speed of establishment, adaptation to different soils across the local area, longevity, ability to reseed, special maintenance requirements, and aesthetics. An important criterion for roadside grasses is their appearance when unmowed. Also, establishment of plants on unpaved portions of the right-of-way stabilizes soil on the surface of slopes and prevents recurring maintenance and sediment pollution (19).

Masiunas and Carpenter (10) stated that seed mixtures result in more productive stands than those produced from seeding a single species. Better cover from mixed stands may be partially explained by varying growth requirements of individual species in seeding mixtures, differences in root quantity, variable root position in the soil, periodicity of growth, and environmental requirements. Establishment of a mixed stand requires the differential germination and seedling

growth of individual species or varieties in the mixture. Also, mixtures accommodate soil variations within a project.

The most critical period for establishing a grass plant is the seedling stage (23). Roadsides should be planted when temperature and moisture conditions are most conducive to plant establishment and growth. A grass seedling is very sensitive to unfavorable moisture conditions (11). Green sprangletop frequently is used in the plant mixture to give a quick cover. As other grasses, such as little bluestem, grow to thicker stands after 3-4 years, the green sprangletop begins to fade (13).

Plants may be thought of as an engineering material for erosion and sediment management (10). A vegetative cover mitigates many of the forces impacting soil stability. The raindrop impact is reduced by interception of the vegetative canopy so that the soil particles will not be loosened and displaced from the surface of the soil. Vegetation slows the velocity of wind or water movement across the soil surface, so the cutting and carrying capacities of wind and water erosive forces are reduced. A decrease in velocity of water runoff allows more water to enter the soil, providing moisture storage for plant growth (11).

After selecting the seed mixture, the objective is to create an environment which favors seed germination and plant establishment. Factors of concern are available moisture and favorable temperatures. Habitat factors may be altered by changing the dates of planting, by applying other cultural practices, or by installing a surface mulch (11).

Slopes with appropriate transitional grading between cuts and fills will improve appearance and highway safety, ease establishment of a vegetative cover, and reduce maintenance costs. Specifications for topsoil vary from state to state, but it is the top layer of soil suitable for agricultural purposes (7). In Texas, topsoil should be spread to depth shown on the plants or directed by the engineers, spread to conform with the designed finish grades, and should not be collected or spread when it is wet (28).

The development of slopes on highway rights-of-way is influenced by the anticipated traffic, the topography, and protection needed against erosion (1). Erosion depends on the force with which the raindrops dislodge the soil and on the speed of runoff. These are dependent upon the length and steepness of the slopes, the texture and structure of the soil, and the vegetative cover (25).

The two most common methods of seeding rights-of-way are drilling and hydroseeding. Drilling places the seed into a shallow furrow opened in the soil; in hydroseeding, the liquid stream incorporates the seed into the surface layers of soil. Various departments of transportation (DOTs) use different methods of planting depending on the site and the resources available to them. Good seed-to-soil contact and an even distribution of the seeds over the target area are essential. Yet another way to establish vegetation is to collect hay from existing plantings and spread it over the area to be revegetated. Seed costs are low, the labor requirement is high, germination may be low, and undesirable species can be introduced. Weed seeds contained in the soil may germinate after site preparation.

Germinating weeds may compete strongly with the planted native vegetation for space and nutrients (21): If desired, maintenance may be used to control the competing weeds.

Both hydroseeding and drill seeding have limitations. Drills are usable on slopes flatter than 6:1. Seed placement is more precise with drilling, but drilling is slower than broadcasting. The seeds usually are placed 6 to 12 mm (.25 to .50 in) below the soil surface (9). Most drill seeders have two or three individual seed boxes which may be calibrated separately to accommodate the different sizes and types of seeds being used. This allows greater flexiablity in designing mixtures of seeds to be used.

The quantity of seed to apply per hectare (acre) depends upon the species. Seeding rates are based on kilograms (pounds) of pure live seed (PLS) per hectare (acre) (27).

Hydroseeding is faster but less precise than drilling. A hydroseeder can seed areas too steep for tractors to travel. Seeding uniformity depends upon a conscientious hydroseeder operator. Hydroseeding is seldom successful without some soil disturbance before the seeding operation, but seems to be more successful where natural settling will cover the seeds.

Installation of a surface mulch is an integral part of a seeding operation for erosion control. Mulches moderate the microclimate and improve seedling establishment by moderating soil temperatures and conserving soil moisture (4,7).

Any material used on the soil surface to prevent water evaporation, to decrease wind and water erosion, to maintain surface structure for good infiltration and prevention of crust formation, to keep down weeds, to decrease fluctuations in temperature, or to promote soil productivity may be called a mulch. Mulching reduces the amount of water reaching the soil on small precipitation events by interception. Different plant species may intercept different amounts of water (14).

Evaporation rate is proportional to the thickness of the mulch. Evaporation of soil moisture from the seed zone can be reduced with a surface mulch for 6 days to 2 weeks, an advantage which can be crucial in the emergence and development of young plants. A hectare (acre) with 1 tonne (0.9 ton) of sorghum residue will produce a good mulch and will equal about 19 mm (.75 in) of rainfall in reduced evaporation of soil moisture. A good mulch helps insure seed germination under low soil moisture, and more than doubles the number of seedlings under high soil moisture conditions (4).

Mulching has become a major part of the seeding operations for erosion control (7). Hay and straw are the most commonly used mulch materials, but others are available. The hay or straw mulch, under most conditions, is held in place by asphalt or other suitable tackifiers. Hay and straw, with or without the addition of asphalt, are mechanically blown onto slopes. Many other materials are currently being used to hold the mulch in place, such as: wooden stakes, chicken wire, jute netting, paper-mesh materials, glass fibers and blankets (7).

Mulch rates depend upon the site's erosion potential, mulching material, and whether a tackifier is added. Hydraulic mulches are available. These currently have no standards for material and equivalent rates of fiber or tackifiers.

Many highway departments use virgin wood manufactured by a leading company because it has longer fibers that slightly increase the water holding and retention capacity. These fiber mulches do not have the adequate mass or fiber length to prevent erosion on severe sites and are ineffective against mass movement of soil. Washington State Transportation Center evaluated the life of wood fiber mulch on a 2.5:1 slope. Estimated life span was 6 months, which effectively reduced erosion by 80-100 percent. The cost of the wood fiber was two-thirds the cost of straw mulches. However, other departments use recycled fibers (usually paper and cardboard) because they are lower in cost and still yield acceptable results.

The Integrated Roadside Vegetation Management Plan through the Iowa DOT recommends the upper limit for use of a hydraulic mulch is a 2:1 slope with a length of 6 m (6.6 yd). An average mulch rate of 2250 kg/ha (2250 lb/ac) is needed for adequate coverage. The logistics of handling, storage, transportation, and cost of mulch must be considered. One metric tonne (2200 lbs) of wood fiber mulch occupies about 6.8 m^3; (8.84 yd^3) and a metric tonne (2200 lbs) of straw would occupy 21.7 m^3 (28.2 yd^3) of storage (2). Certain mulches, especially straw and wood-fiber, actually improve the soil environment and allow fast seedling establishment.

Hydraulic tackifiers are available as powders or concentrated liquids. They can be sprayed alone or in the slurry mix of mulch, seed, and fertilizer. These tackifiers function as a binding agent to hold fibers and soil particles together after drying. Application rates vary widely depending upon the product used (2).

STUDY SITES

Coleman

Coleman has a subhumid climate and moderate temperatures (Figure 1). It lies in the transitional zone between the humid climate of East Texas and the semiarid climate to the west and northwest. The average annual rainfall is 687 mm (27.48 in) with most falling from April through October with peaks in May and September. Much of the rain comes from thunderstorms. Large seasonal variations in temperature are characteristic. In winter, temperature changes rapidly as cold, dry, polar air alternates with warm moist, tropical air from the Gulf of Mexico. Summers are hot, with several consecutive days having temperatures over 38° C (100.4° F). Most soils have weakly developed profiles. Calcium carbonate remains in the soil as caliche. The dominant grasses in this area are little bluestem, yellow indiangrass, and sideoats grama (25).

Two freshly-cut roadside sites with a total area of 1.71 ha (4.28 ac) were chosen along SH 153, 12.5 km (7.5 mi) and 23.7 km (14.22mi) west of its junction with SH 206 and US 84/283 in Coleman. Topsoil came from a local haul and was applied to a depth of 10-20 cm (4-8 in) along FM 153. The soil analysis showed the pH was moderately alkaline at 8.1; nitrogen, phosphorus and sodium were very low; magnesium, zinc, iron, manganese, copper and sulphur were at a high concentration; potassium and calcium were very high.

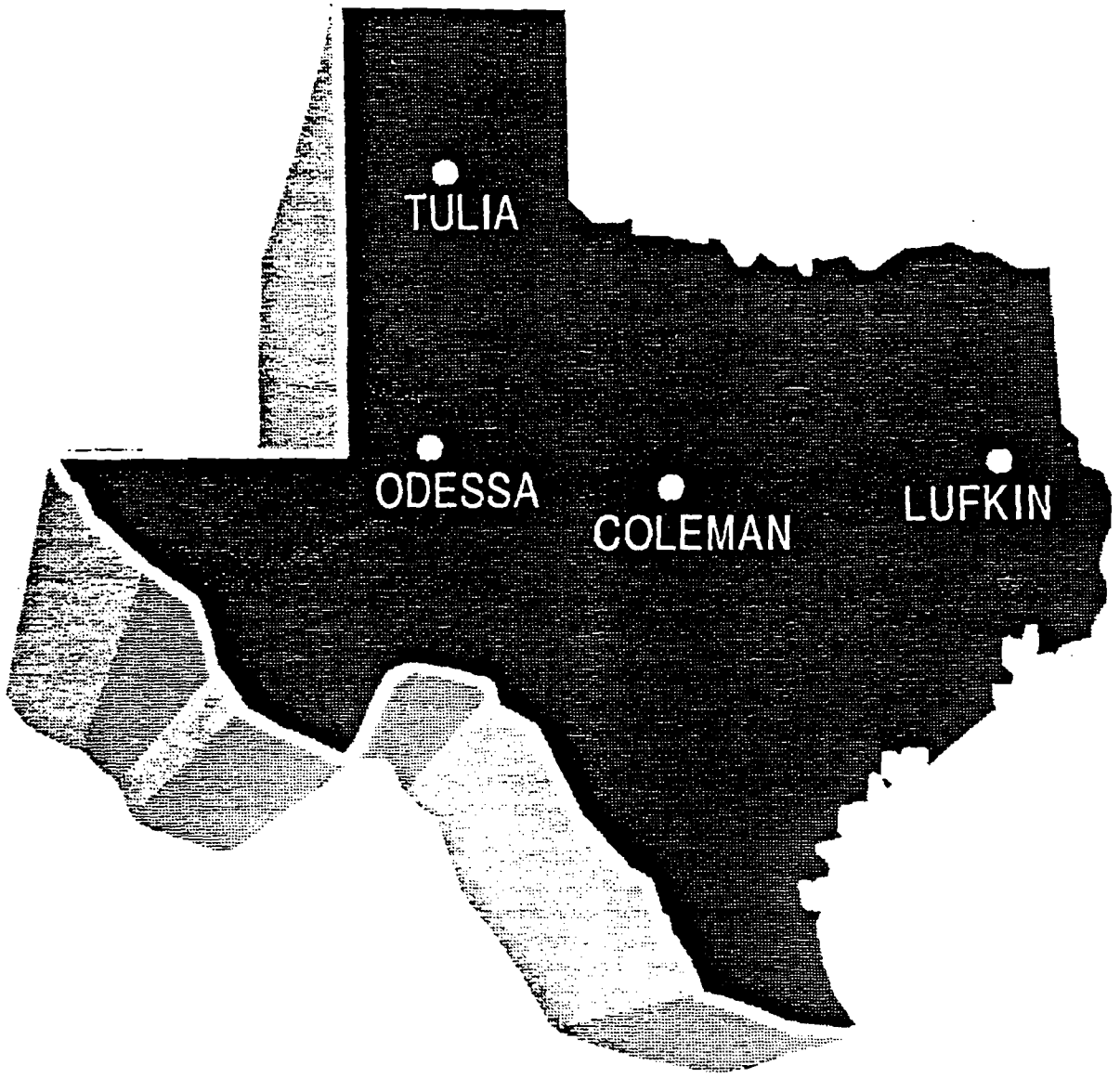

Figure 1. Seeding study test sites.

Lufkin

Two sites were seeded in the Lufkin District area (Figure 1). One site was along SH 103 with 0.67 ha (1.68 ac), and the other was along FM 3451 at its junction with US 96 and had 0.78 ha (1.95 ac). The site on SH 103 is 1.6 km (1 mile) from the "Entering Angelina Forest" sign coming from Lufkin. This site has cut slopes along both sides of the road. The drainage and permeability of the soil were poor at this location. The climate is humid. The mean annual precipitation ranges from 1010-1524 mm (40.4 - 60.96 in). Mean annual temperature ranges from 17 to 21° C (62.6 to 69.8° F). The forest is made up of blackgum, sweetgum, post oak, and water oak. Dominant grasses in this area include blackseed needlegrass, Canada wildrye, eastern little bluestem, giant cane and purpletop. Topsoil was from material on cut slopes, and was moderately acidic with a pH of 6.8. Nitrogen and phosphorus were ranked very low; sodium was low; copper, iron, magnesium, manganese, potassium, sulphur, and zinc were high; and calcium was very high at 5469 ppm.

The second site was at the intersection of US96 and FM 3451, a fill slope, north of San Augustine on both sides of FM 3451. The soils were a well-drained gravelly clay loam. Permeability was moderately slow. Climate is humid and warm. Annual precipitation is about 1220 mm (48.8 in) and mean annual temperature is about 19° C (66.2° F). The mixed pine-hardwood forest consists of shortleaf and loblolly pine, sweetgum, and southern red oak. The soil analysis ranked nitrogen, phosphorous and sodium as very low; potassium, calcium, magnesium, iron, manganese, sulphur as high; zinc and copper as low. The soil was mildly alkaline at 7.4 pH.

Odessa

Odessa is located in an arid area (Figure 1). Winters are mild, but have frequent cold fronts accompanied by strong, gusty, northerly winds. Extreme surface winds occur in early March. Blowing dust occurs when wind velocities are 48 kph (28.8 mph) or higher. During most dust storms, visibility ranges from 1.6 to 4.8 km (1 to 2.9 mi). The surface layers of unprotected slopes are susceptible to soil blowing.

The predominant wind is from the south-southeast. The average annual relative humidity is about 75% at 6:00 a.m., but it drops to about 45% at noon and 37% at 6:00 p.m. Thus, the rate of soil water evaporation is very high. High winds cause considerable soil movement (24).

Dominant grasses in this area are black grama, blue grama, cane bluestem, hooded windmillgrass, perennial three-awn, plains bristlegrass, sand dropseed, sideoats grama, silver bluestem, and vine mesquite. Invaders in this area are mesquite and yucca.

Rainfall averages only about 356 mm (14.24 in) annually. About 74% of this falls in the form of thundershowers from May to October. Data on the total annual rainfall are often misleading, because the large amount of rainfall in wet years falls during heavy thundershowers and runs off rapidly. Droughts are rather frequent in Odessa (24).

This location of 3.0 ha (7.5 ac) divided among 4 qurdrants of filled slopes was at the interchange of Loop 250 and SH 158, also known as SH 191. Topsoil for the slope was not used. Fill material was present, which consisted of a gravelly sandy loam used to build the approach ramps. Analysis of the soil showed the pH to be moderately alkaline; phosphorus and sodium were low, iron was deficient, and potassium, calcium, magnesium, zinc, manganese, copper and sulphur ranked high. The nitrogen level varied from very low on the north-facing slope to very high on the south-facing slope.

Tulia

Tulia is located in a semi-arid area with mild winters (Figure 1). Average annual precipitation is 444 mm (17.76 in) and approximately 79% falls from May to October. Average annual relative humidity varies from 72% at 6:00 a.m. to 40 percent at 6:00 p.m. The prevailing winds blow soil and other debris over the slopes. High wind movement and reduced water intake by slowly permeable soils on backslopes create stressful conditions for vegetative growth (26).

The test site was located on Intrastate Highway 27 at exit 74 immediately south of SH 86. Planting areas were cutslopes on the backslopes on opposing sides of the main lanes of IH 27. The topsoil for the slopes was taken from a nearby pit. Analysis of the soil showed it was moderately alkaline, with 44.3% clay and 29.3% silt. Nitrogen, zinc, copper and sodium content were very low, while phosphorus, potassium, calcium, magnesium, iron, manganese and sulphur were considered high.

Tulia is located in a nearly level, short-grass prairie. The potential plant community on this site consists of short grasses, mainly blue grama and buffalograss. Other grasses found in the area are sideoats grama and threeawns.

METHODS

Seed mixtures and planting rates for each location are listed in Table 1.

Table 1. Seeding specifications for the various research sites.

Site and Species	Rate kg/ha *
Coleman	
Buffalograss	5.9
Green sprangletop	0.7
Little bluestem	1.2
Sideoats grama cv. Haskell	2.0
Yellow Indiangrass cv. Cheyenne	1.7
Lufkin	
Bermudagrass (Common)	1.0
Green sprangletop	0.8
Little bluestem	1.6
Switchgrass	1.6
Yellow Indiangrass	2.0
Odessa	
Black grama	0.6
Blue grama cv. Hachita	0.9
Green sprangletop	1.0
Little bluestem	2.2
Sideoats grama cv. Vaughn	3.1
Sideoats grama cv. Haskell	2.0
Yellow Indiangrass	2.0
Tulia	
Blue grama	0.9
Buffalograss	9.0
Green sprangletop	1.0
Sideoats grama cv. El Reno	3.1

* kg/ha = lb/ac

Site Preparation

Prior to planting, all litter, debris, stones, roots, wires, stakes, and other objects that would interfere with planting or maintenance operations were cleared from the soil surface. Grading the site established a smooth, firm seedbed. Rilling could occur if the soil was too loose. The seedbed was scarified using a maintainer fitted with scarifier teeth chisels to a depth of 10 to 13 cm (4 to 5.2 in), making the seedbed more receptive to plant root growth. Since a mixture of different size seed was used, the planting depth was determined by the smallest seed.

Although the amount of precipitation received on an area could not be controlled, the seeding time was planned for the beginning of the spring rains to provide the best growing conditions. Most parts of Texas receive significant rainfall in early to mid-spring except Odessa. Odessa receives its primary rainfall from June to August.

Planting and Mulching Techniques

Two common seeding techniques for slopes and rights-of-way used are hydroseeders and grass seed drills. A hydroseeding technique was used to broadcast seeds in a stream of water with a fanning motion over the slope. Seed and fertilizer, when used, were kept suspended by mechanical agitation. The seeds that were to be hydroseeded were mixed in a slurry of water and distributed through a jet stream of water onto the slopes. The water and seed were sprayed within 30 minutes or less so the seeds would not begin to sprout. This was especially important if fertilizer was also applied with the seed slurry. Tanks of water containing seed were not kept overnight. Application was done uniformly in a set swath using a sweeping motion with the nozzle. The nozzle was elevated enough that the larger seeds were not rolled over the ground.

Grass seeds were also planted using a grass drill. Grain drills could not be used to plant grass seed because the seed could not be metered properly and would be planted too deeply. Grass drills used were made by Nesbit, Truax or Tye. Grass seed drills were equipped with 2 or 3 individual seed boxes for contrasting chaffy and fine seeds. The chaffy box contains a picker-wheel mechanism with oversized teeth; this mechanism meters the seeds into the seed tubes. Small seeds were metered by adjusting the size of the opening of the gate through which the seed dropped. Each seedbox was adjusted independently. The seeds fell through flexible seed tubes into small furrows 20 cm (8 in) apart, and 1.3 cm (.5 in) deep formed in the soil using double-disc furrow openers. The seed was covered using a packer wheel. Care was taken in mixing the seed for planting, because hard or slick seed would settle out of the mixture of fluffy seed, giving an uneven seeding rate.

After the seeds were sown, a mulch of grass hay at the rate of 0.7 tonne per ha (.77 ton/acre) was spread over the designated portions of the newly seeded areas to provide temporary erosion control and moisture retention. A straw blower was used to beat and break the hay bales into a size that the blower could handle. The mulch was evenly distributed in a fan-like motion through an air

stream. After the hay mulch was in place, it was tacked with emulsified asphalt using a hand sprayer.

Vegetation Measurements

Measurements were along a random pace transect in each treatment. Evaluation of plant frequency was done with fifty observations of 0.1 m^2 (.12 yd^2) quadrats per treatment. The quadrat was placed at the toe of shoe and a visual rating of the presence or absence of individual plant species was made. Establishment was evaluated over a 3-year period. One plant per 0.1 m^2 (.12 yd^2) was assumed to be adequate coverage or a full stand. Visual aerial and basal cover ratings were obtained in 1991, after three growing seasons. Cover was evaluated by the same fifty observations used for frequency, 0.1 m^2 (.12 yd^2) quadrats per treatment, at the toe of shoe.

Analysis

The analysis was done according to a split-plot ANOVA with a 2 X 2 factorial with four replications and time as the split. The main plot was a 2 X 2 factorial using mulch and method of seeding. Time was the subplot. Differences were determined using the F statistic at the alpha = 0.05 level, and mean separation with Duncan (16). An individual analysis was done for each location. Locations were not considered as an additional factor (16, 18).

RESULTS AND DISCUSSION

Comparison of grass stands from seedings made in 1989 could promote the selection of species, seeding method, and the use of a hay mulch. All seedings were installed in April around the favorable annual rainfall. These studies were analyzed individually.

Coleman

On September 15, 1990, two seasons after seeding on April 11, 1989 the average frequency of each species planted per treatment were determined. Sideoats grama occurred most frequently in all treatments, ranging from 26 to 40% (Table 2). Little bluestem was the least frequent in all treatments, except it was the same as green sprangletop in the No-Mulch treatments. Buffalograss, yellow indiangrass, and green sprangletop varied in numbers. Yellow Indiangrass and little bluestem were present in similar numbers of quadrats in all treatments.

Table 2. Frequency (%) of occurrence of each species seeded April 11, 1989, on plots established near Coleman, Texas, and evaluated September 15, 1990.

Species	Treatment[a]			
	Mulch		No Mulch	
	Broadcast	Drill	Broadcast	Drill
	---------- Frequency (%) ----------			
Planted Grasses				
Buffalograss	12 b	13 b	27 a	19 ab
Green sprangletop	12 a	4 b	2 b	4 b
Yellow Indiangrass	9 a	8 a	4 a	9 a
Little bluestem	2 a	1 a	2 a	1 a
Sideoats grama	26 b	40 a	31 b	31 b

[a]Values across rows followed by the same letter are not significantly different at the 5% level using Duncan's multiple range test.

On October 30, 1991 the average frequency of each species planted per treatment were evaluated (Table 3). Sideoats grama increased in frequency from 1990 and occurred in all treatments and was the prevalent grass planted. Buffalograss decreased in frequency across all treatments. Little bluestem and green sprangletop's frequency increased in all treatments except green sprangletop in the Mulch-Drill treatments. The frequency of yellow Indiangrass doubled from 1990 to 1991 in almost all treatments except the Mulch-Broadcast. Silver bluestem occurred most frequently in the No-Mulch-Broadcast treatment. Other grasses and forbs occurred in varying numbers.

From the second to the third year (Table 2, 3), buffalograss tended to decrease slightly in frequency, green sprangletop remained about the same, and yellow indiangrass, little bluestem, and sideoats grama increased.

Table 3. Frequency (%) of occurrence of each species seeded April 11, 1989, on plots established near Coleman, Texas, and evaluated October 30, 1991.

Species	Treatment[a]			
	Mulch		No Mulch	
	Broadcast	Drill	Broadcast	Drill
	---------- Frequency (%) ----------			
Planted Grasses				
Buffalograss	10 b	9 b	20 a	12 b
Green sprangletop	13 a	1 b	6 ab	4 ab
Yellow Indiangrass	7 a	17 a	10 a	16 a
Little bluestem	9 a	7 a	9 a	6 a
Sideoats grama	38 c	46 a	41 b	44 ab
Other Grasses and Forbs				
Silver bluestem	4 a	4 a	12 a	1 a
Other grasses	6 a	t[b] b	2 b	3 ab
Other forbs	7 ab	2 b	12 a	8 ab

[a]Values across rows followed by the same letter are not significantly different at the 5% level using Duncan's multiple range test.

[b]Present but less than 1% frequency

The aerial cover for the planted species were rated at Coleman. Sideoats grama was the most common under all treatments (Table 4). The highest rating of sideoats grama was the Mulch-Drill treatment. Buffalograss in both drill treatments were significantly different from the broadcast treatments. Green sprangletop had the most cover in the Mulch-Drill treatment. Both broadcast treatments of little bluestem had better cover results than the drill treatments. Both little bluestem and yellow Indiangrass occurred in similar numbers, respectively regardless of treatment.

Table 4. Percent aerial vegetative cover of grasses seeded April 11, 1989, and indigenous species plus litter and bareground on plots established near Coleman, Texas, and evaluated October 30, 1991.

Species	Treatment[a]			
	Mulch		No Mulch	
	Broadcast	Drill	Broadcast	Drill
	Cover (%)			
Planted Grasses				
Buffalograss	3 b	9 a	2 b	7 a
Green sprangletop	1 b	6 a	3 b	1 b
Little bluestem	4 a	2 b	4 a	2 ab
Sideoats grama	19 c	31 a	22 bc	24 b
Yellow Indiangrass	6 ab	4 b	9 a	6 ab
Other Grasses	1 ab	t[b] b	2 ab	2 a
Silver bluestem	t b	2 a	2 a	1 b
Litter	5 c	8 ab	7 b	9 a
Bareground	65 a	44 c	56 b	55 b

[a]Values across rows followed by the same letter are not significantly different at the 5% level using Duncan's multiple range test.

[b]Present but less than 1% cover.

Basal cover for the plants at Coleman varied according to species. Sideoats grama had the best cover in all treatments (Table 5). The Mulch-Drill treatment of sideoats grama rated the highest cover and was significantly different from the other treatments. Both drill treatments were better than the broadcast treatments for buffalograss and sideoats grama. Other grasses and forbs were present in small numbers, but will not be identified for this paper. Other grasses were present most frequently in the Mulch-Broadcast and No-Mulch-Drill treatments. Other forbs and silver bluestem occurred least in the Mulch-Drill treatment. Litter was the highest in No-Mulch-Drill treatment. Both Mulch-Drill and No-Mulch-Broadcast were not significantly different in litter. Bareground was significantly different in every treatment, with the highest and lowest ratings in the mulch treatments.

Table 5. Percent basal vegetative cover of grasses seeded April 11, 1989, and indigenous species plus litter and bareground on plots established near Coleman, Texas, and evaluated October 30, 1991.

Species	Treatment[a]			
	Mulch		No Mulch	
	Broadcast	Drill	Broadcast	Drill
	----------Cover (%)----------			
Planted Grasses				
Buffalograss	3 b	9 a	2 b	7 a
Green sprangletop	1 b	5 a	2 b	1 b
Little bluestem	3 a	1 b	3 a	2 ab
Sideoats grama	16 b	24 a	17 b	18 b
Silver bluestem	t[b] c	2 a	1 ab	t bc
Yellow Indiangrass	5 ab	3 b	6 a	4 ab
Other Grasses	t b	t b	1 ab	2 a
Forbs	1 b	1 ab	1 ab	2 a
Litter	5 c	8 ab	7 b	9 a
Bareground	67 a	47 d	60 b	56 c

[a]Values across rows followed by the same letter are not significantly different at the 5% level using Duncan's multiple range test.

[b]Present but less than 1% cover.

These results show that each of the five seeded species could be established under any of the planting and mulching combinations. There was no clear advantage to mulching versus non-mulching or broadcast versus drilling of seeds. The cover supported the findings for frequency.

Although plant size was not measured, the plants tended to be larger the third year. Sideoats grama, in particular, produced large basal clumps the third year which would be efficient for erosion control, whereas they were only small plants the second year.

The lack of a better stand of green sprangletop may reflect a low seeding rate or quicker germination of other grasses (seeding was done during a drizzle at the beginning of 3 days of rain, and cloudy weather). The month of April in 1989, had 35 mm (1.4 in) of rain, followed by large amount of rain in May and June (Table 6), but the average rainfall for 1989 was lower than the yearly average of 687 mm (27.48 in). Sideoats grama and buffalograss were quick to establish. Little bluestem and yellow Indiangrass were slow to start but were increasing by the end of the

second year following seeding. The second and third year were substantially higher in rainfall than the yearly average. Under different circumstances and different locations the results may have been different.

Table 6. Precipitation on seeding study from January, 1989 to October, 1991 near Coleman, Texas.

Month	Year		
	1989	1990	1991
	Rainfall (mm) *		
January	18	79	20
February	116	82	22
March	45	56	17
April	35	162	37
May	123	73	94
June	118	13	202
July	48	175	277
August	29	43	130
September	82	150	304
October	32	74	123
November	8	73	---
December	6	15	---
Total per year	661	995	1226

*25 mm = 1 in

Lufkin

The average frequency of each species planted was evaluated on July 12, 1989 (Table 7). Green sprangletop occurred most frequently in the mulch treatments, ranging around 40%, while the No-Mulch treatments ranged around 20%. Thus, the green sprangletop apparently had a high germination and survival rate after planting. The bermudagrass had the highest frequency for the No-Mulch. Frequency of little bluestem ranged from 11 to 22%. The highest frequency of little bluestem occurred in the Mulch-Drill treatment. The lowest frequency occurred in the No-Mulch-Broadcast treatment. Switchgrass was not significantly affected by Mulch-Broadcast treatment. Yellow Indiangrass was not prevalent in the different treatments.

Table 7. Frequency (%) of occurrence of each species seeded April 4, 1989, on plots established near Lufkin, Texas, and evaluated July 12, 1989.

Species	Treatment[a]			
	Mulch		No Mulch	
	Broadcast	Drill	Broadcast	Drill
	Frequency (%)			
Planted Grasses				
Bermudagrass	30 b	40 a	29 b	27 b
Green sprangletop	40 a	41 a	26 b	23 b
Yellow Indiangrass	2 a	2 a	1 a	1 a
Little bluestem	19 a	22 a	11 b	17 a
Switchgrass	12 a	6 a	6 a	5 a

[a]Values across rows followed by the same letter are not significantly different at the 5% level using Duncan's multiple range test.

The average frequency for each planted species was evaluated on September 25, 1991 (Table 8). Green sprangletop was present only at a trace in the Mulch-Broadcast treatment. Bermudagrass occurred more often in the No-Mulch treatments, while the yellow Indiangrass occurred most often in the Mulch treatments. Overall, yellow Indiangrass occurred the most in all treatments, ranging from 18 to 35%. No difference was found in the little bluestem's frequency across all treatments. The number of switchgrass plants ranged around 8 to 9%, except for the Drill-Mulch treatment.

Table 8. Frequency (%) of occurrence of each species seeded April 4, 1989, on plots established near Lufkin, Texas, and evaluated September 25, 1991.

Species	Treatment[a]			
	Mulch		No Mulch	
	Broadcast	Drill	Broadcast	Drill
	Frequency (%)			
Planted Grasses				
Bermudagrass	1 b	2 b	8 a	8 a
Green sprangletop	t[b] a	0 a	0 a	0 a
Yellow Indiangrass	35 a	33 a	23 b	18 b
Little bluestem	6 a	6 a	4 a	4 a
Switchgrass	9 a	2 b	8 a	8 a

[a]Values across rows followed by the same letter are not significantly different at the 5% level using Duncan's multiple range test.

[b]Present but less than 1% frequency.

Yellow Indiangrass had the highest cover of species in all the treatments (Table 9). The highest ratings of the yellow Indiangrass were in the two No-Mulch treatments, followed by the Mulch-Broadcast at 9% then the Mulch-Drill at 5%. Green sprangletop did not have a significant stand in any treatment. Little bluestem cover was about 1% across all treatments. Switchgrass cover was not significant cover in the mulch treatments, but had 4 to 6% in the No-Mulch treatments. No difference was found between the Bermudagrass treatments around 1%, except the No-Mulch-Drill at 3%.

The non-planted grasses, especially crabgrass, varied in cover from a trace to 9%. Crabgrass was most predominate in the No-Mulch-Drill treatment. Significantly lower crabgrass ratings were found in the two broadcast treatments from a trace to 1%. Other grasses and forbs were present, but will not be identified for this paper. Other grasses were not significantly different in each of the four treatments, ranging in cover from 2 to 3%. The other forbs had about 2 to 5% cover across all treatments. Bareground was the most prevalent in the Mulch treatments with a significant difference between the Mulch and the No-Mulch treatments. Litter was around 17 to 25% in all treatments.

Table 9. Percent aerial vegetative cover of grasses seeded April 4, 1989, and indigenous species plus litter and bareground on plots established near Lufkin, Texas, and evaluated September 25, 1991.

Species	Treatment[a]			
	Mulch		No Mulch	
	Broadcast	Drill	Broadcast	Drill
	Cover (%)			
Planted Grasses				
Bermudagrass	1 b	1 b	0 b	3 a
Green Sprangletop	t[b] a	0 a	0 a	0 a
Yellow Indiangrass	9 b	5 c	15 a	18 a
Little Bluestem	1 a	2 a	2 a	1 a
Switchgrass	t b	1 b	6 a	4 a
Non Planted Grasses				
Crabgrass	t c	5 b	1 c	9 a
Other Grass	3 a	2 a	2 a	3 a
Forbs				
Other Forbs	2 b	4 a	2 b	5 a
Litter	17 b	25 a	22 ab	25 a
Bareground	74 a	72 a	63 b	47 c

[a]Values across rows followed by the same letter are not significantly different at the 5% level using Duncan's multiple range test.

[b]Present but less than 1% cover.

On September 25, 1991, of the planted species, yellow Indiangrass had the most basal cover in all treatments (Table 10). The green sprangletop was almost nonexistent in all treatments. Bermudagrass, little bluestem, and switchgrass ranged in cover from a trace to 3% in the four treatments. No differences were found across the treatments except for bermudagrass in the No-Mulch-Drill treatment, which showed a significant difference.

The non-planted grasses such as crabgrass had 4% cover in Mulch-Drill and 8% cover in No-Mulch-Drill. The cover was comparable among both broadcast treatments. Other grasses were present at about 2%, but will not be identified for this paper. Other forbs, species not shown, ranged in cover around 10% for both broadcast treatments and 13 to 14% in the drill treatments. Litter was the highest in the drill treatments at 25%, and the lowest cover in the Mulch-Broadcast treatment. Bareground was the highest in the Mulch-Broadcast treatment, followed by the No-Mulch-Broadcast. No difference was found between the two drill treatments at 42 to 47%.

Table 10. Percent basal vegetative cover of grasses seeded April 4, 1989, and indigenous species plus litter and bareground on plots established near Lufkin, Texas, and evaluated September 25, 1991.

Species	Treatment[a]			
	Mulch		No Mulch	
	Broadcast	Drill	Broadcast	Drill
	----------Cover (%)----------			
Planted Grasses				
Bermudagrass	1 b	1 b	t[b] b	3 a
Green Sprangletop	t a	0 a	0 a	0 a
Yellow Indiangrass	9 a	5 bc	7 ab	4 c
Little Bluestem	1 a	1 a	1 a	1 a
Switchgrass	2 a	1 a	1 a	1 a
Non Planted Grasses				
Crabgrass	t c	4 b	1 c	8 a
Other Grass	1 a	2 a	2 a	3 a
Forbs				
Other Forbs	10 b	13 ab	10 b	14 a
Litter	17 b	25 a	22 ab	25 a
Bareground	61 a	47 c	55 b	42 c

[a]Values across rows followed by the same letter are not significantly different at the 5% level using Duncan's multiple range test.

[b]Present but less than 1% cover.

From the second (data not shown) to the third year (Table 9, 10), green sprangletop and switchgrass were quick to establish. Yellow Indiangrass was slow to start but was increasing by the end of the second year following seeding. Green sprangletop, little bluestem, and switchgrass tended to decrease slightly in numbers. The green sprangletop probably died out because it is more adaptable to dry climates, and because it is not very competitive with other plants. Considering all the species, there was no clear advantage to either mulching treatment or planting method and green sprangletop could have been deleted from seed mix.

The high amount of rain falling in May and June of 1989 did seem to affect the cover to some extent (Table 11). The seeds and mulch were probably washed down the hill, thus having a greater density at the foot of the slopes. All three years have had an extraordinary amount of rainfall. Average rainfall is 1220 mm (48.8 in). Plants are there in number, but the cover area is still small.

Table 11. Precipitation on seeding study from January, 1989 to October, 1991 near Lufkin, Texas.

Month	Year		
	1989	1990	1991
	Rainfall (mm) *		
January	194	191	230
February	44	117	2
March	154	117	36
April	30	57	165
May	170	439	132
June	359	96	83
July	112	98	155
August	68	37	216
September	75	65	75
October	57	72	49
November	48	95	---
December	54	120	---
Total per year	1364	1502	1143

* 25 mm = 1 in

Odessa

On October 9, 1991 the average frequency of each species per treatment was evaluated (Table 12). Blue grama occurred most frequently in the Mulch-Broadcast, but barely rated in the rest of the treatments. Black grama and green sprangletop varied across all treatments. Little bluestem was found only in the Mulch-Broadcast treatment. Yellow Indiangrass was not present in any treatment.

Table 12. Frequency (%) of occurrence of each species seeded April 18, 1989, on plots established near Odessa, Texas, and evaluated October 9, 1991.

Species	Treatment[a]			
	Mulch		No Mulch	
	Broadcast	Drill	Broadcast	Drill
	---------- Frequency (%) ----------			
Planted Grasses				
Black Grama	3 b	17 ab	12 ab	13 ab
Blue Grama	9 b	2 b	1 b	1 b
Green sprangletop	4 a	7 a	6 a	8 a
Little bluestem	6 a	0 a	0 a	0 a
Sideoats grama	6 ab	13 a	10 ab	12 ab
Yellow Indiangrass	0 b	0 b	0 b	0 b

[a]Values across rows followed by the same letter are not significantly different at the 5% level using Duncan's multiple range test.

The low occurrence of each of the species may be related to receiving only half the 356 mm (14.24 in) of annual rainfall in 1989 (Table 13). With the low rainfall and probable high winds uncovering and moving the seed, the plants were unable to germinate and survive in these conditions.

Table 13. Precipitation on seeding study from January, 1989 to October, 1991 near Odessa, Texas.

Month	Year		
	1989	1990	1991
	Rainfall (mm) *		
January	6	5	46
February	33	277	6
March	9	24	0
April	1	50	0
May	24	9	14
June	16	0	89
July	9	42	216
August	30	55	40
September	71	73	96
October	4	37	15
November	1	19	---
December	4	18	---
Total per year	207	609	521

* 25 mm = 1 in

On October 9, 1991, of the planted species, sideoats grama had the most aerial cover under Mulch-Broadcast (Table 14), although not significantly different. Black grama, blue grama, and green sprangletop cover was similar in all treatments. Cover of planted grass species varied from a trace to 4% across all treatments.

The non-planted grasses and forbs ranged from 1 to 11% cover in any of the four treatments. Chloris spp. had the highest cover in all four treatments ranging from 9 to 11%. Tumbleweed was present, as were other forbs that will not be identified. Tumbleweed was the most prevalent in the Mulch-Broadcast treatment. Bareground and litter was not significantly different, ranging from 61 to 63% and 7 to 11%, respectively.

Table 14. Percent aerial vegetative cover of grasses seeded April 18, 1989, and indigenous species plus litter and bareground on plots established near Odessa, Texas, and evaluated October 9, 1991.

Species	Treatment[a]			
	Mulch		No Mulch	
	Broadcast	Drill	Broadcast	Drill
	----------Cover (%)----------			
Planted Grasses				
Black grama	1 a	3 a	4 a	4 a
Blue grama	t[b] a	t a	1 a	t a
Green sprangletop	1 a	1 a	1 a	2 a
Sideoats grama	2 a	2 a	2 a	4 a
Yellow Indiangrass	0 a	0 a	0 a	0 a
Non Planted Grasses				
Bermudagrass	6 a	4 a	5 a	3 a
Common sandbur	4 a	4 a	3 a	4 a
Purple three-awn	2 a	4 a	2 a	2 a
Chloris spp.	10 a	9 a	11 a	9 a
Other grass	1 a	3 a	3 a	2 a
Forbs				
Tumbleweed	8 a	5 a	1 a	5 a
Other forbs	3 a	4 a	4 a	3 a
Litter	11 a	7 a	11 a	8 a
Bareground	63 a	63 a	63 a	61 a

[a]Values across rows followed by the same letter are not significantly different at the 5% level using Duncan's multiple range test.

[b]Present but less than 1% cover.

Sideoats grama had the most basal cover under Mulch-Broadcast (Table 15). The Black grama stand had the highest cover in the Mulch-Drill, No-Mulch-Broadcast, and the No-Mulch-Drill, but there were no significant differences. Blue grama and green sprangletop were similar in all treatments.

The non-planted grasses and forbs ranged from 1 to 7% cover in any of the four treatments. The non-planted grasses were Bermuda, common sandbur, purple three-awn, chloris spp. and other grasses that will not be identified for this paper. Chloris spp. and Bermudagrass had 6 and 5% cover respectively for Broadcast-Mulch. Chloris spp. remained highest in all treatments with a range of 6 to 7% with no significant difference. The forbs were tumbleweed and other forbs which will not be identified for this paper. Tumbleweed was the highest in the Mulch-Broadcast, Mulch-Drill, and the No-Mulch-Drill treatments. Litter ranged from 7 to 11% across all treatments. Bareground ranged 62 to 66% across all treatments.

Table 15. Percent basal vegetative cover of grasses seeded April 18, 1989, and indigenous species plus litter and bareground on plots established near Odessa, Texas, and evaluated October 9, 1991.

Species	Treatment[a]			
	Mulch		No Mulch	
	Broadcast	Drill	Broadcast	Drill
	----------Cover (%)----------			
Planted Grasses				
Black grama	1 a	2 a	3 a	3 a
Blue grama	t[b] a	t a	t a	t a
Green sprangletop	1 a	1 a	1 a	2 a
Sideoats grama	1 a	1 a	1 a	3 a
Yellow Indiangrass	0 a	0 a	0 a	0 a
Non Planted Grasses				
Bermudagrass	5 a	3 a	4 a	2 a
Common sandbur	3 a	4 a	3 a	4 a
Purple three-awn	2 a	2 a	1 a	1 a
Chloris spp.	6 a	6 a	7 a	6 a
Other grass	1 a	2 a	2 a	1 a
Forbs				
Tumbleweed	6 a	4 a	1 a	4 a
Other Forbs	2 a	3 a	3 a	3 a
Litter	11 a	7 a	11 a	8 a
Bareground	62 a	66 a	62 a	64 a

[a]Values across rows followed by the same letter are not significantly different at the 5% level using Duncan's multiple range test.

[b]Present but less than 1% cover.

Chloris spp. and Tumbleweed are invaders which were most likely carried in the wind or were present in the top soil. The frequency of black grama occurred more than the cover showed in the Mulch-Drill and also for blue grama Mulch-Broadcast. Yellow Indiangrass and little bluestem could have been left out of the mixture.

Tulia

On October 10, 1991 the average frequency of each species per treatment were evaluated (Table 16). Green sprangletop was the most frequent species in all treatments, ranging from 84 to 99%. More than one species could occur in the plot at any given time. Both drill treatments of blue grama had 13% frequency, with the broadcast treatments ranging 3 to 7%. Sideoats grama had a good stand in each treatment, ranging from 11 to 26%

Table 16. Frequency (%) of occurrence of each species seeded April 25, 1989, on plots established near Tulia, Texas, and evaluated October 10, 1991.

Species	Treatment[a]			
	Mulch		No Mulch	
	Broadcast	Drill	Broadcast	Drill
	---------- Frequency (%) ----------			
Planted Grasses				
Blue grama	3 c	13 a	7 b	13 a
Buffalograss	4 b	9 a	1 c	7 ab
Green sprangletop	84 b	99 a	92 ab	92 ab
Sideoats grama	17 b	26 a	17 b	11 c

[a]Values across rows followed by the same letter are not significantly different at the 5% level using Duncan's multiple range test.

On October 10, 1991, sideoats grama had the most aerial cover under the Mulch-Broadcast and the No-Mulch-Broadcast (Table 17). The buffalograss stand was the highest in the Mulch-Drill and the No-Mulch-Drill treatment.

The non-planted grasses and forbs ranged from 0 to 2% for any of the species except Johnsongrass in the Mulch-Drill treatment.

Table 17. Percent aerial vegetative cover of grasses seeded April 25, 1989, and indigenous species on plots established near Tulia, Texas, and evaluated October 12, 1991.

Species	Treatment[a]			
	Mulch		No Mulch	
	Broadcast	Drill	Broadcast	Drill
	----------Cover (%)----------			
Planted Grasses				
Blue Grama	3 ab	2 ab	3 a	2 b
Buffalograss	6 b	13 a	8 b	14 a
Green Sprangletop	4 ab	3 b	6 a	4 b
Sideoats Grama	9 a	6 b	8 a	6 b
Non Planted Grasses				
Common Sandbur	t[b] b	1 ab	0 b	1 a
Johnsongrass	2 b	4 a	1 b	1 b
Chloris spp.	t a	1 a	1 a	1 a
Texas Wintergrass	1 a	2 a	1 a	1 a
Other Grasses	2 a	2 a	2 a	1 a
Forbs				
Carelessweed	1 a	1 ab	t b	1 ab
Sil.Leaf Nightshade	t a	t ab	t b	t ab
Other Forbs	1 a	1 a	1 a	1 a
Litter	15 a	10 b	15 a	10 b
Bareground	63 a	62 a	61 a	62 a

[a]Values across rows followed by the same letter are not significantly different at the 5% level using Duncan's multiple range test.

[b]Present but less than 1% cover.

Sideoats grama had the most basal cover of the planted species under Mulch-Broadcast (Table 18). The buffalograss stand had the highest basal cover in the Mulch-Drill, No-Mulch Broadcast and No-Mulch Drill. Blue grama cover was similar in all treatments. The planted grass species varied in cover from 1 to 14% across all treatments.

The non-planted grasses and forbs ranged from 0 to 2% cover in any of the four treatments. The non-planted grasses were common sandbur, Johnsongrass, chloris spp., Texas wintergrass and other grasses that will not be identified for this paper. The forbs were carelessweed, silverleaf nightshade and other forbs that will not be identified for this paper. Litter was the highest in the

No-Mulch Broadcast, but not different from Mulch Broadcast. The two drill treatments showed no difference between each other. Bareground was high across all treatments, ranging from 61-63%, with no differences between treatments. The two broadcast treatments of litter were the same statistically, and significantly different from the two drill treatments, which were also the same statistically.

These results show that each of the four seeded species could be established under any of the planting and mulching combinations. Buffalograss had the highest coverage for 3 out of 4 treatments in the basal cover, and 2 out 4 for the aerial coverage. Sideoats grama ranked highest in basal coverage for the Mulch-Broadcast treatment and for the two drill treatments in the Aerial cover. The lack of a better stand of blue grama may reflect a low germination rate or quicker germination of other grasses. Green sprangletop had a high frequency of occurrence but a low level of coverage, probably due to not much basal growth.

The low rate of coverage for each species was probably due to insufficient rainfall at the time of planting (Table 19). Although 1989's rainfall was over the yearly average of 444 mm (17.76 in) and 1990 was below the yearly average. The number of non-planted grasses and forbs were probably from the original topsoil or from being carried in with the wind. There was no difference between Mulch and No-Mulch, so the difference can not be related to the hay mulch.

Table 18. Percent basal vegetative cover of grasses seeded April 25, 1989, and indigenous species plus litter and bare ground on plots established near Tulia, Texas, and evaluated October 12, 1991.

Species	Treatment[a]			
	Mulch		No Mulch	
	Broadcast	Drill	Broadcast	Drill
	Cover (%)			
Planted Grasses				
Blue Grama	2 ab	2 ab	2 a	1 b
Buffalograss	6 b	13 a	8 b	14 a
Green Sprangletop	3 ab	2 c	4 a	3 bc
Sideoats Grama	7 a	5 bc	7 ab	5 c
Non-Planted Grasses				
Common Sandbur	t[b] a	1 a	t a	1 a
Johnsongrass	1 b	2 a	1 b	t b
Chloris spp.	t b	0 ab	t ab	1 a
Texas Wintergrass	1 a	2 a	1 a	1 a
Other Grasses	2 a	1 a	2 a	1 a
Forbs				
Carelessweed	1 a	t ab	t b	1 ab
Sil.Leaf Nightshade	t a	t a	t a	0 a
Other Forbs	1 a	1 a	1 a	1 a
Litter	15 a	10 b	15 a	10 b
Bare Ground	63 a	62 a	61 a	62 a

[a]Values across rows followed by the same letter are not significantly different at the 5% level using Duncan's multiple range test.

[b]Present but less than 1% cover.

Table 19. Precipitation on seeding study from January, 1989 to October, 1991 near Tulia, Texas.

Month	Year		
	1989	1990	1991
	Rainfall (mm) *		
January	11	24	19
February	18	48	1
March	21	21	16
April	1	58	0
May	76	46	70
June	154	12	117
July	15	49	139
August	100	48	40
September	60	39	90
October	3	14	11
November	0	33	---
December	8	2	---
Total per year	466	393	503

* 25 mm = 1 in

CONCLUSIONS

A protective cover of vegetation modifies many of the forces concerned in soil erosion. While a grass cover can often be achieved naturally in time, it is desirable to reduce the erosion risk and shorten the time to establish a stand of grass by employing cultural methods such as seeding and mulching techniques. Grasses for roadsides should be planted when temperature and moisture conditions are most favorable (11). Consequently, germinating seeds are very sensitive to unfavorable moisture and temperature conditions as expressed at Odessa, while the other sites showed the benefit of good precipitation. Generally, the difficulties of obtaining a good stand of grass for erosion control increase as one proceeds westward across Texas (12).

Plants should be chosen that are adapted to the area. According to McCully, Larsen, and Hill (1963), green sprangletop is known to have a rapid rate of germination and seedling development. Green sprangletop showed the same results at Lufkin, but disappeared after the first year because it was out of its range. Plantings of perennial grasses should persist and furnish protection from erosion after the green sprangletop disappears.

At Coleman, no significant differences were attributed to mulch or seeding method. By end of the second growing season, sideoats grama and buffalograss were the most frequent, with other species present in varying degrees. By the end of the third growing season, buffalograss declined; green sprangletop remained about the same, and little bluestem and sideoats grama increased in number. Yellow Indiangrass doubled in frequency from 1990 to 1991. Sideoats occurred most often and had the best cover.

At Lufkin, no differences in frequency resulted from mulch or seeding method. By the end of the first growing season, green sprangletop was the most frequent grass with the most cover. Switchgrass was also good for coverage at this area, and other species varied in degrees. By the end of third growing season green, sprangletop disappeared from the stand and switchgrass had declined and yellow Indiangrass increased in coverage.

At Odessa, no significant differences occurred due to mulch or seeding method. By the end of the third growing season, black grama, green sprangletop, and sideoats grama were the most prevalent species.

Overall, no difference occurred in stands at Tulia due to mulch or seeding method. By the end of the third growing season, green sprangletop was the most prevalent plant in all treatments, followed by sideoats grama. By the end of third growing season, buffalograss and sideoats grama had the most cover, with other species present in varying degrees.

Although the grasses did not show a difference among treatments, there was a good coverage on a majority of the slopes. Erosion was not as great as it would have been if no treatment had been performed. Green sprangletop came up initially at Lufkin and Coleman, then decreased as the other species began to grow. This was supported by Duell (1989).

The wind and water erosive forces were reduced on these highway slopes by selecting plants that favored seed germination and plant establishment for each location. Cutting down the eroding capacities of the wind and water allowed more water to enter the soil, which enhanced plant establishment.

Since most treatments are costly, the size of the state budget will influence and control the number and source of treatments. Ideally the treatments are selected to yield the greatest cover within the available budget. The different seeding methods or addition of mulch did not show a difference at these locations. The climate was unusual over the study period. The author would recommend the Drill-Mulch technique in most circumstances, because the seed can be placed more precisely in the soil. However, on steep slopes, hydroseeding is more beneficial and lower costs can be realized.

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APPENDIX I

The common and scientific names of grasses and plants:

Common names	**Scientific names** (7)
Barley	*Hordeum vulgare*
Bermudagrass	*Cynodon dactylon*
Black grama	*Bouteloua eriopoda*
Blackgum	*Nyssa sylvatica*
Blackseed needlegrass	*Piptachaetium avenaceuna*
Blue grama	*Bouteloua gracilis*
Buffalograss	*Buchloe dactyloides*
Canada wildrye	*Elymus canadensis*
Cane bluestem	*Bothriochloa barbinodis*
Careless weed	*Amaranthus retroflexus*
Common sandbur	*Cenchrus incertus*
Crabgrass	*Digitaria spp.*
Eastern little bluestem	*Schizachyrium scoparium* var. *divergens*
Giant cane	*Arundinaria gigantea*
Green sprangletop	*Leptochloa dubia*
Hooded windmill	*Chloris cucullata*
Johnsongrass	*Sorghum halepense*
Little bluestem	*Schizachyrium scoparium*
Loblolly pine	*Pinus taeda*
Mesquite	*Prosopis glandulosa*

APPENDIX I (CONTINUED)

Common names	Scientific names
Oats	*Avena fatua*
Plains bristlegrass	*Setaria macrostachya*
Postoak	*Quercus stellata*
Purple three-awn	*Aristida purpurea*
Chloris spp.	*Chloris spp.*
Sand dropseed	*Sporobolus cryptandrus*
Shortleaf pine	Pinus echinata
Sideoats grama	*Bouteloua curtipendula*
Silver bluestem	*Bothriochloa laguroides*
Silver leaf nightshade	*Solanum elaegnifolium*
Sorghum	*Sorghum vulgare*
Southern red oak	*Quercus falcata*
Sweetgum	*Liquidambar styraciflua*
Switchgrass	*Panicum virgatum*
Texas wintergrass	*Stipa leucotricha*
Three awns	*Aristida spp.*
Tumbleweed	*Salsola iberica*
Vine mesquite	*Panicum obtusum*
Water oak	*Quercus nigra*
Yellow Indiangrass	*Sorghastrum nutans*
Yucca	*Yucca torreyi*