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16. Abstract

Native varieties of grasses, having evolved over many eons, have clearly demonstrated their ability to withstand harsh environmental conditions and create stable vegetation communities. The Texas Department of Transportation (TxDOT) has been seeding native grass species along with adapted grass species as part of its vegetation establishment program for many years. Over the past decade, the use of native grasses has greatly increased as more people have become aware of their restoration and habitat advantages as well as their beauty. TxDOT would like to test the feasibility of using an all-native species seeding mix for use in the establishment of roadside vegetation in roadway construction projects. This project surveys available native grass species and tests selected varieties as part of a mix under roadside conditions to determine which if any, may be desirable additions to the current seeding program.

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DISCLAIMER

This research was performed in cooperation with the Texas Department of Transportation (TxDOT) and the Federal Highway Administration (FHWA). The contents of this report reflect the views of the authors, who are responsible for the facts and the accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the FHWA or TxDOT. This report does not constitute a standard, specification, or regulation.

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This project was conducted in cooperation with TxDOT and FHWA.

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BACKGROUND AND SIGNIFICANCE OF WORK

Native varieties of grasses, having evolved over many eons, have clearly demonstrated their ability to withstand harsh environmental conditions and create stable vegetation communities. The Texas Department of Transportation (TxDOT) has been seeding native grass species along with adapted grass species as part of its vegetation establishment program for many years. Over the past decade, the use of native grasses has greatly increased as more people have become aware of their restoration and habitat advantages as well as their beauty. TxDOT wanted to test the feasibility of using an all-native species seeding mix for use in roadside vegetation establishment in roadway construction projects. This project surveys available native grass species and tests selected varieties as part of a mix under roadside conditions to determine which, if any, may be desirable additions to the current seeding program. The report discusses the issues related to the nature of native grass culture within the roadside environment and includes guidance on the use of native grasses in the roadside. The project also investigates the effects of increased seeding rates of selected grass species and the effect of higher rates of compost-derived nitrogen fertilizers on plant growth and nutrient leaching.

The hardiness and longevity of native plants under severe environmental conditions are well documented, and many state departments of transportation (DOTs) have begun to incorporate native species into their vegetation programs (Daar and King 1997; Harrington 1991). Because local plants evolved under the regional or even local conditions where they are found, they are considered by definition best suited to thriving in that environment (Wathern 1977). Research largely affirms this theory although plant adaptability is thought to vary greatly from one plant species to another. Plants of a local area (often referred to as eco-types) also have intimate connections with the fauna of a given area, so using native plants helps preserve existing native insect, bird, and mammal populations (Seabrook and Dettmann 1996; Camp and Best 1994). Native plants are often regarded as part of an historical context and may be preferred so as to maintain the botanical and aesthetic heritage of a locale (Martz 1986; Bassett 1999). Additionally, many native plants are attractive as individuals and as part of larger communities.

All these factors have led to increased attention on native plants by national, state, and local agencies as well as non-governmental agencies such as restoration groups and native plant organizations. In most parts of the country, the use of native plants on the roadside is a more recent phenomenon than in Texas. TxDOT has been at the forefront of innovative roadside re-vegetation with native plants for many years. With the support and encouragement of Lady Bird Johnson, TxDOT pioneered the use of wildflowers as a standard roadside practice and set a standard that is the envy of many other states. Although the wildflowers were primarily intended for aesthetic enhancement, TxDOT recognized the importance of native species and expanded their use. In the late 1980s TxDOT developed a seeding specification that relied heavily on native grass varieties (TxDOT 1993). The current seeding specification now includes 23 grasses, 14 of which are native varieties.

Historically, most commercially grown seed was developed to meet the demand of livestock producers. Many of the species were newly introduced varieties that could withstand heavy grazing use. The most sought-after grasses were those that provided large amounts of palatable livestock forage coupled with rapid growth and fast regeneration. Species availability began to expand as the USDA initiated its Conservation Reserve Program. This voluntary program paid landowners to abandon some grazing pastures for a period of years if they would re-seed with suitable grasses. As a response to this need, the USDA Plant Material Centers collected and tested native seed. Species that showed promise for commercial production as well as forage capability were reproduced and provided to commercial producers who then grew and offered them for sale to landowners.

Role of Vegetation on the Roadside

Vegetation within the roadside plays a critical role although this role typically goes unnoticed by the general public. In fact, the roadway infrastructure is dependent on a stable environment to maintain its structural integrity. Were the soil to wash away, in most cases, the structures would go with it. Vegetation prevents eroded soils from encroaching on travel lanes and creating a driving hazard. Siltation from unstable soil landscapes can clog drainage structures causing water to encroach on driving lanes. Cleaning structures is a necessary and costly operation. Vegetation provides the stability to the ground surface that protects downstream water bodies and habitat (and its associated wildlife) from the damage due to siltation and contaminant transfer.

The importance of this function of vegetation forms the basis of the U.S. Environmental Protection Agency (EPA) to set standards governing the establishment of vegetation on roadway construction projects. This standard, TPDES General Permit No. TXR150000, pursuant to Section 26.040 of the Texas Water Code and Section 402 of the Clean Water Act, specifies that in order to receive final termination on the project, the vegetation must attain 70 percent of adjacent native vegetative cover. Until this requirement is met, the project cannot be closed and finally accepted by the state department of transportation. This delay results in added costs to the contractors and the DOT, driving up the cost of roadway construction. Consequently TxDOT and other DOTs are always looking for ways to develop more effective seeding programs.

One additional requirement is that stabilization measures must be initiated within 14 days, and if construction activities have ceased, they will not resume for 21 days. TxDOT currently meets this requirement by including both warm and cool season temporary seeding mixes. These mixtures will not be considered as part of this project since they are intended for areas likely to be disturbed again before construction has ended.

TxDOT's Approach to Seeding

TxDOT's approach to the use of native grass seed in the development of its seed mixes is based on three components, (1) the use of "nurse species," (2) matching local conditions, and (3) plant structure:

1. Nurse species are plants that germinate quickly, stabilize the area, and afford protection to other slower-growing species. This is crucial since many native grasses will not show significant above-ground plant mass until their root systems are well developed. In some cases this may require two or more growing seasons.
2. TxDOT has tailored the species used in the mixes as closely as possible to the predominant soils and climate of the region in which they will be used, based on whether they will be used in urban or rural locations. A special category of seed mixes was also

developed to provide temporary erosion control for projects that must be seeded in the cool parts of the year. This special category has resulted in over 50 different mix combinations, as each is assigned specific planting dates and seeding rates based on the region in which it is used.

3. The structure of many permanent, warm-season varieties of grass is that of a bunch-forming growth habit that leaves soil between the plants exposed to the elements. To fill this niche, TxDOT's mixes include sod-forming varieties that will fill the spaces in order to provide complete erosion protection.

In addition to these basic criteria, TxDOT has selected species based on their reliability in germination, their tolerance of unavoidable disturbances, their likelihood of availability in sufficient quantities, and their cost. These latter issues are a response to the unique and demanding conditions of the roadside and practical contracting requirements. Selected plant species must not only be attainable but must be able to survive the environmental conditions of a given site and thrive while exposed to a number of conditions not found in undisturbed, native landscapes.

Seeding rates affect establishment and survivability. Higher seeding rates might result in faster establishment to meet minimum cover requirements. This will result in higher seeding costs. Also, a higher mortality due to increased competition with more plants may result in a cover that is equivalent to lower and less costly seeding rates within a specific period of time. This study examined a set of modified seeding rates to determine the effect of higher seeding rates on vegetation establishment and overall project costs.

Management Conditions

Vegetation management's first two goals are: 1) a safe environment for the driving activity and 2) the protection of the roadbed and the structures on or near it from the effects of erosion. These two goals are intertwined since serious erosion or siltation of drainage structures can easily lead to unsafe driving conditions. Other than erosion, the most critical safety issue is vegetation height and its effect on visibility within the roadway. Intersecting roads and driveways pose highly dangerous situations if obscured. Tall vegetation can also obscure the slope and location of the ground surface as well as objects such as drainage structures in the roadside that may otherwise be avoided by vehicles leaving the paved surface. These needs are met through an integrated use of mowing and herbicides.

The management of vegetation on the roadside is unlike plant management in any other context. While management in a typical commercial landscape exercises control over access to the site, management along the roadsides does not. Roadsides are completely open and subject to frequent disturbances from maintenance and construction practices, utility access, accidental runoffs by drivers, or intentional use by adjacent landowners. Examples of these disturbances include:

- Regular upgrades of the paved surface are a common disturbance that typically impacts the areas closest to the travel surface but equipment and material storage as well as access can affect much larger areas.
- Private citizens often assume control over the right-of-way in front of their properties by mowing the roadside. Ranchers or farmers may harvest grass as hay from the roadside, and commercial property owners may use the right-of-way as storage or display space.
- The highway right-of-way also serves as a major corridor for water, electric, and communications utilities. Periodic disturbances often result from needed repairs, replacements and upgrades, new connections, and maintaining adequate clearance for aboveground transmission lines.

The results of these issues and activities, whether planned or unplanned, combine to create a very dynamic environment. The effect of this dynamism is that the conditions required for the development of a stable, diverse, native plant community are very rare. This does not mean that native plants are inappropriate for the roadside, only that the suitability of a candidate species must be based largely on its individual adaptability and much less on its role as part of complex and closely interdependent plant community. However, this adaptability does not necessarily need to be universal to all roadside areas. TxDOT’s mowing practices, when combined with favorable roadway widths and profiles have created niches for plants with narrower ranges of cultural needs.

Mowing and Its Effect on Plant Community Composition

Mowing is by far the most common and the most visible disturbance to roadside vegetation. Consequently, public comment about the practice is common. Over the past 10 years, TxDOT has modified its practice of mowing the entire right-of-way width in rural areas to a15 to 30-foot strip along the edge of the travel lane. In rural corridors, this strip often coincides to the location of drainage swales, leaving the back-slope of the swale and any shelf area undisturbed for longer periods of time.

This practice has created a roadside profile with distinct zones by vegetation type (Ullmann et al. 1995). A narrow strip adjacent to the pavement typically contains annual, low-growing species that can tolerate frequent tracking, little water, and high heat levels. The balance of the area of strip mowing contains grasses and forbs that have fairly low growth habits and a greater percentage of annual species (annual wildflowers adapt best in this zone). The centerline of a swale is typically in this zone and, due to more moisture or deeper soils, may contain taller-growing grasses and forbs. The back-slopes and shelf (which receive less mowing) contain fewer annual species and more perennial, warm-season species. Typically, a wider range of larger native plants is found in this latter zone. This condition suggests the possibility that some species of native grasses that would otherwise not be suited for the roadway may have application in some conditions.

The Role of Seeding in Long-Term Vegetation Development

Roadside vegetation studies have documented, and simple observation confirms, that the composition of roadside vegetation a period of years after seeding bears little resemblance to the limited number of species that comprised the initial seeding. This is a significant observation in that it indicates the important role played by adjacent vegetation in the process of revegetation. The full extent and mechanism of this relationship is not yet documented.

Regardless of the initial seeding mix, the ultimate vegetation community will be determined by three interacting processes: 1) the initial seed varieties planted, 2) the management practices employed (or other disturbances) in the roadside, and 3) the normal process of ecological succession, whereby nearby existing plants, both native and introduced, will gradually colonize the newly seeded roadside.   This informs us that the main emphasis on the initial seeding composition should logically be one of stabilization as well as long-term species composition.

The linear nature of the roadway supports this supposition. Plant species ultimately sort themselves within a community based on micro-conditions of soil (Yantis 1991), slope, nutrient level, moisture, and competition with adjacent plants. All of these components vary (frequently and often abruptly) as the roadway crosses diverse soil types, many of which have been drastically disturbed during the construction process. A seeding program designed to establish a specific, ultimate plant community composition would necessarily have to account for each unique condition in order to achieve its goal. Clearly, such a task would be a monumental undertaking and even then doubtful to achieve the desired results since future conditions cannot be predicted.

TxDOT has a well-established seeding program that includes native seed that has been proven highly effective. Some native seed currently available has a “fluffy” nature that requires special mechanical adaptations for use. TxDOT has much experience with these issues and so the mechanics of the seeding operation were not explored as part of this project. Seeding and management of the study plots will follow standard TxDOT procedures as found in specifications and guidelines (TxDOT 1993; Northcutt 1993) in use at the time of the study.

This project is an experimental investigation to document and compare the performance of existing TxDOT seed mixtures and alternative pure native grass seed mixtures. The tests document the rate of establishment, height, percentage of vegetative cover, and reaction to disturbance. The experiments were conducted as field trials and in controlled greenhouse conditions.

PROJECT OBJECTIVES

Increased Seeding Rate Evaluation

TxDOT uses the National Resource Conservation Service (NRCS) Critical Application Rate to determine and establish seeding rates for each district. This standard is considered an acceptable balance between vegetative cover, costs, and plant viability. There have been questions raised as to whether or not increasing this seed rate standard might improve the speed of cover establishment in new seeding projects. In response to this question, the Houston and San Angelo Districts have established an additional seeding rate which requires a substantially higher seed count and additional added species than the specified TxDOT standard seeding rate. This project examined the two different rates and compared the different rates in terms of speed of vegetative cover and viability over time. These two rates will be referred to as Increased District Rate 1 (Houston) and Increased District Rate 2 (San Angelo).

Native Seed Mix vs. TxDOT Standard Mix

Spurred by the increased demand by homeowners and restorationists, private companies have begun to grow and collect native seeds, further expanding availability. Native grasses are increasingly being promoted for landscape and lawn use and for pasture renovation. It has been suggested that TxDOT should establish an all-native seed mix as an option to its established standard seed mixes which it currently uses. This project will examine an all-native seed mix, compare it to the TxDOT Standard mix, and compare establishment rate and cover. This project will also examine which of the native and introduced grass varieties in each of the seed mixes performed well and are beneficial to TXDOT for use in its re-vegetation program.

Compost Derived Nitrogen Fertilizer Leachate Study

In addition to this difference in seed mix rates several districts also use a different organic fertilizer application rate. The standard TxDOT rate is 100 lb/acre of nitrogen, 50 percent of which must be slow release. Some districts use an organic fertilizer at a rate of 4000 lb/acre. In addition to this, these districts also use compost as a soil amendment in its vegetation program. Improving soil nutrient content in impoverished soils will encourage a quicker vegetative cover.

The amount of nutrient loading may involve added costs. The rate of nutrient loading should be a balance between the amount of nutrients that plants can take up within a given period, the amount of nutrients subject to leaching from the site, and the cost impacts to the project. Time-released fertilizers may moderate leaching so that not all the potential nutrient is immediately available. However, an increase in nutrient levels beyond that needed for successful establishment may result in the need for added mowing later on due to increased grass growth.

Soil nutrient resources affect the amount of vegetative biomass (plant cover) that occurs within a given period of time. Applying supplemental nutrients at high rates may result in greater plant cover in a shorter period of time. However, nutrients not taken up by plants may leach into water bodies causing algae blooms and/or excess phosphate accumulation. This study examined a set of modified nutrient sources and application rates to compare the effects on plant cover rates, nutrient leaching, and project costs.

LITERATURE REVIEW

Historical Background

The never-ending debate concerning native plants versus non-native plants for roadside vegetation makes a DOT's ultimate decision extremely difficult. Studies advocate that native plants are more beneficial because of their durability in the long run, maintaining that since certain species occur naturally in an area, they should clearly be more resilient towards harsh weather conditions characterized by that specific region. Counter arguments claim that aside from not adapting well in the long run, the disadvantages of non-native grasses also include problems in providing the right cover for wildlife, dispersing to other places they should essentially evade, and crowding other native vegetation, like wildflowers (Coleman 1996). Nonetheless, the premise behind the native versus non-native argument lies in a dichotomy between the durability versus rapidity of roadside vegetation establishment and soil conservation.

SEED AVAILABILITY AND COST SUMMARY

Economic Trends

Throughout the past decade, the native seed industry has experienced multiple changes in economic trends such as fluctuation in supply and demand, changes in the business, structure of the industry, influence of the federal government as a buyer, and changes in species availability (Dunne and Dunne 2003).

The early1990s saw the rapid expansion of the coal industry and mine reclamation, which generated a high demand for native seeds for projects in the western United States. Relative to the market as a whole, private environmental nonprofit organizations were large purchasers of native seeds from 1992 to 1998, but their demand fell significantly in the latter part of the 1990s (Dunne and Dunne 2003). In addition, the occurrence of massive wildfires sparked a demand for seeds for fire reclamation throughout the late 1990s along with the rising popularity of native seed species. Furthermore, the native seed industry simultaneously witnessed the quadrupling of prices between 1997 and 1999.

The native seed industry shifts in prices are probably the most drastic trend changes. By the late-1980s, prices began to drop largely due to surplus seeds and drought delays in seed planting. Prices started to rise steadily in 1993 once marketers realized that they had nearly used up all of the surplus seeds and land was below the recent demand. However, during 1997, prices doubled with increased demand due to fires and the second round of the Conservation Reserve Program (CRP) (Dunne and Dunne 2003). In 1999, 2 million acres of Nevada's rangeland was consumed by fire; 600,000 acres burned in 2000. More acres were burned in these two years than the previous 40 years combined. Large demand for rehabilitation of Nevada's rangelands spiraled prices even further. In addition to Nevada's fire rehabilitation, Montana and Idaho experienced massive wildfires of their own, thus causing further demand for fire rehabilitation. Seeds were pulled out of cleaning mills before they could even reach warehouse shelves…prices increased in the fall of 2000 when it was realized that an entire year's supply of seeds were in demand even before they could be conditioned (Dunne and Dunne 2003).

According to Richard A. Dunne and Claire Gabriel Dunne's article "Trends in the Western Native Plant Seed Industry since 1990," this anomaly between price and demand in the native seed industry is primarily due to producer-product cycle. Within the seed industry, immutable lags occur between supply and demand (Dunne and Dunne 2003). Also, native grasses take a long time to produce their full seed potential. Most of them do not reach their full seed potential until the second or third year of production. Usually the cycle starts with low prices and low supplies. New demand subsequently raises prices. Supplies increase to catch up with demand and eventually exceed demand. Finally, prices drop and supplies contract (Dunne and Dunne 2003).

Production and marketing in the native seed industry has also undergone a shift in trends. According to Dunne and Dunne, a decade ago approximately 80 percent of native seeds produced by growers were sold to marketers for resale to retailers. Today, around 70 percent of the production is contracted to specific marketers before the crop is even planted, and they set terms on producers to varying degrees. Dunne and Dunne expect large producers to start marketing their own seeds, especially through Internet advertising.

As for future trends in the seed industry, Dunne and Dunne expect that cheatgrass-engendered fires will continue to rise in size and frequency in the Great Basin. Furthermore, they also assert that species in demand will be determined by multiple criteria such as price and availability; but demand will be increasingly dominated by political and philosophical considerations until research resolves such issues as the relative merits of local ecotypes versus improved cultivars, or the use of annual cover crops in perennial native-seed mixes (Dunne and Dunne 2003).

Surveying Seed Suppliers

In order to determine the availability and cost of native grass seed, researchers distributed surveys with a list of the native grasses used for this project to six seed companies in May 2004.

The surveys asked questions regarding general seed availability, seed availability from year to year, and cost. The four seed companies who responded to the survey were the following: Bamert Seed Co., Douglas W. King Seed Co., Native American Seed Co., and Turner Seed Co.

Many of the surveys were returned incomplete providing varied results; therefore, only generalized assertions could be made regarding native seed cost and availability. Using the survey results and comments noted from conversations with representatives of various native seed companies, the researchers were able to establish some general conclusions regarding availability and pricing of individual native grasses.

Seed Availability

While most of the native grasses were readily available, seeds from several of the native grasses on the list were considered difficult to obtain. Among those grasses were *Aristida purpurea,* Purple Threeawn; *Stipa leucotricha*, Texas Wintergrass; *Elymus elymoides,* Bottlebrush Squirreltail; *Andropogon glomeratus*, Bushy Bluestem; *Oryzopsis hymenoides*, Indian Ricegrass; and *Muhlenbergia wrightii,* Spike Muhly. In addition to harvest difficulties, producers have stated that the availability of these grasses is low because of little demand.

Many of the large seed suppliers grow and harvest the majority of their own seed. The native seed varieties which have high demand from year to year are grown in fields owned by the seed company or the company uses contract growers. The native grasses which have lower demand are obtained through other companies or the native seed supplier will try to find established plots of that particular species and arrange contracts for harvest. Many native seed varieties and mixes come from fields where a seed supplier has negotiated an arrangement to harvest native stands of grasses and forbs.

The availability of native seed is largely determined by the demand for that seed. Representatives from native grass seed companies stated that species would become more readily available if TxDOT were to write specifications for the use of a particular native grass currently with little demand. These specifications would depend upon adequate supplies of the grass readily available for harvest. However, according to the seed suppliers, even with uncommon varieties of native grasses, if demand was there for a seed, the companies would find ways to make it available.

Seed Cost Variabilities

The individual cost of native grass seed varies considerably from species to species. However, there seems to be a correlation between price and demand. As a general rule, the higher the demand, the cheaper the price. The Texas Bluebonnet is an example of a native species that first entered the commercial market at a price of approximately $30/lb, and as demand and availability increased the price per pound went down to the current price of approximately $7/lb.

The seed cost chart below supports the fact that the initial cost of the more difficult to obtain and low demand native seeds is higher than those of more commonly used native grasses. According to Jay Kane at Native American Seed Co., current seed prices for commonly sold seeds are at an all-time low. Kane noted that prices fluctuate and are closely tied to the Conservation Reserve Program. He noted that a historic benchmark for seed prices fluctuated between $10–15/lb. Short term changes in price for a seed no longer in demand or suddenly in demand could range up or down 270 percent. Table 1 lists the different prices per unit.

Table 1. Seed Cost Chart as of May 2004

Name of Seed	Cost	Unit
Sporobolus airoides, Alkali Sacaton	$9.50	LB
***Bouteloua gracilis* 'Hachita',** Blue Grama 'Hachita'	$7.00	LB
Buchloe dactyloides, Texoka Buffalograss	$5.00	LB
Sporobolus cryptandrus, Sand Dropseed	$4.00	LB
Hilaria jamesii, Galleta 'Viva'	$16.00	LB
Schizachyrium scoparium, Little Bluestem	$7.50	LB
Andropogon hallii, Sand Bluestem	$5.00	LB
Bouteloua Curtipendula, Sideoats Grama 'El Reno'	$3.25	LB
Leptochloa dubia, Green Sprangletop	$4.50	LB
Eragrostis trichodes, Sand Lovegrass	$4.00	LB
Setaria macrostachya, Plains Bristlegrass	$9.00	LB
Desmanthus illinoensis, Illinois Bundleflower	$4.00	LB
Eragrostis curvula, Weeping Lovegrass 'Ermello'	$9.00	LB
Cassia fasciculate, Partridge Pea	$11.00	LB
Petalostumum purpureum, Purple Prairieclover	$22.00	LB
Cynodon Dactylon, Common Bermuda	$6.25	LB
Stipa leucotricha, Texas Wintergrass	$75.00	LB
Native Coastal Prarie Mix	$39.00	LB
Aristida purpurea, Purple Three-Awn	$49.95	LB
Andropogon glomeratus, Bushy Bluestem	$89.00	LB
Coreopsis lanceolata, Lanceleaf Coreopsis	$18.50	LB

(Note: The current harvest [2004] contains Little Bluestem, Split Beard Bluestem, Big Bluestem, Broomsedge Bluestem, Balsamgrass, Florida Paspalum, Red Lovegrass, Tall Dropseed, Scratch Dropseed, Slender Paspalum, Knotroot Bristlegrass, Wild Indigo, Croton Gayfeahter, Sunflower, Ragweed, Wild Bean, Gaura, Indiangrass, Three Awn spp, Purpletop, Aster, Vervain, Switchgrass, Marsh Elder, and Partridge Pea.)

Concluding Remarks

The majority of the native grasses used for this TxDOT research project are available in large quantities. The few grasses that are not readily available are not currently harvested in great amounts due to lack of demand or because the species is not as readily available. If demand increases for these grasses, the production and availability should also rise, and the corresponding cost should decrease.

NEW APPLICATIONS AND STRATEGIES FOR NATIVE PLANTS

In order for the native plant industry to overcome its challenges and take advantage of opportunities pertaining to roadside vegetation, new strategies such as partnerships between different types of organizations are vital for progress. In an article entitled "Roadside Revegetation of Forest Highways," found in the Native Plants Journal, Landis et al. report a new partnership between the Western Federal Lands Highway Division of the Federal Highway Administration and the USDA Forest Service, leading to an increased focus on using native plants. New applications for many native plant species, as well as the development of new stock types, innovative equipment, and monitoring techniques have been introduced as a result of such partnerships. The process of road planning and development has become more holistic and comprehensive, allowing engineers and biologists to work in partnerships to bring about desired results (Landis 2005). In addition to these beneficial partnerships, regardless of the lack of published research regarding native plants and the traditional use of non-native species, evidence has proven that native plant species (including grasses, forbs, woody shrubs, and trees) not only ameliorate the disturbance of road construction, but also help blend road rights-of-way back into the adjacent plant community. Therefore, strategies which facilitate the advancement of native plant usage are always in high demand.

RECENT TRENDS IN SEED CHOICE

Various trends pertaining to roadside vegetation decisions have also evolved recently. State DOTs are aiming toward site-specific goals rather than implementing all-encompassing type practices. In particular, seed choice is becoming much more specialized, targeting the best plant for a site rather than a quick selection (Beecham). Carefully considered decisions regarding seed choice enable roadside revegetation to be less of a gamble and maximize a project's potential for long-lasting success. For instance, Beecham notes that southern California prefers low- or no-irrigation plantings because these plants are able to survive in areas where the water supply is low. He also discusses Georgia's increased use of common Bermuda grass particularly because of its drought tolerance, claiming that "the fescues here struggle in the heat…Bermuda grass thrives in the heat" (Beecham). By taking on a more site-specific approach, project managers are able to undertake projects with less of a risk.

UPCOMING PLANT RELEASES

Throughout the course of this project, we have encountered numerous potential plant releases rumored to be released by September 2006. The following releases were reported in the Year 2005 Progress Report of Activities of the E. "Kika" de la Garza Plant Materials Center (PMC) in Kingsville, Texas. This 91-acre facility provides cost-effective vegetative solutions for soil and water conservation problems mainly found in the South Texas area. The native plants identified by the Kika de la Garza PMC are pending the approval of the Plant Materials Center, South Texas Natives Project (STN), and the Texas Agricultural Experiment Station (TAES) in Beeville.

Upcoming Releases Anticipated for September 2006 (Progress Report of Activities for E. "Kika" de la Garza Plant Materials Center 2006):

The PMC is the lead on the following six releases:

1. Welder Gemplasm shortspike windmillgrass
   Chloris subdolichostachya
   Anticipated Select Release Accession # 9085260
2. Mariah Germplasm hooded windmillgrass
   Chloris cucullata
   Anticipated Select Release Accession # 9085313
3. Kika648 Germplasm plains bristlegrass
   Setaria vulpiseta
   Anticipated Select Release Accession # 9029648
4. Kika677 Germplasm streambed bristlegrass
   Setaria leucopila
   Anticipated Select Release Accession # 9029677
5. Kika819 Germplasm streambed bristlegrass
   Setaria leucopila
   Anticipated Select Release Accession # 9038819
6. Kika820 Germplasm streambed bristlegrass
   Setaria leucopila
   Anticipated Select Release Accession # 9038820

STN is the lead on the following four releases:

7. Dilley Germplasm slender grama
   Bouteloua repens 4 combined accessions
8. Chaparral Germplasm hairy grama
   Bouteloua hirsute 4 combined accessions
9. Atascosa Germplasm Texas grama
   Bouteloua rigidiseta 4 combined accessions
10. La Salle Germplasm Arizona cottontop
    Digitaria californica 12 combined accessions

Other current native seed releases as well as pending releases have been identified by the James E. ‘Bud’ Smith Plant Materials Center in Knox City, Texas. This facility proposes and develops state-of-the-art plant science technology in order to provide resource needs in erosion control (wind and water), range and pasture improvement, wildlife habitat improvement, and water quality. The Knox City PMC reported the following new Select Ecotype releases in their Year 2003 Progress Report (Year 2003 Progress Report of Activities for the James E. ‘Bud’ Smith Plant Materials Center 2004):

1. Cottle County Germplasm sand bluestem
   Andropogon hallii
   Accession # 9031498
   Originally collected in Cottle County, Texas, sand bluestem is a native, perennial warm-season grass that grows primarily on sandhills and in deep sandy soils in the Central Rolling Red Plains and Southern High Plains of Texas and Oklahoma. It replaces big bluestem on sandier soils in western Texas and SW Oklahoma. This grass species can be planted in pure stands or as a component in a seed mix. Possible uses of sand bluestem include CRP or Environmental Quality Incentives Program (EQIP) planting on sandy soils, dune stabilization, herbaceous wind barrier, rangeland improvement, and pasture or hayland plantings.
2. OK Select Germplasm little bluestem
   Schizachyrium scoparium
   Accession # 9029926
   A composite of five accessions from native stands from Caddo, Grady, Jefferson, Stephens, and Washita counties of Oklahoma, little bluestem is a native, perennial, warm-season bunchgrass that may be used in pure stands for pasture and hay plantings or as a component in seed mixtures for range seeding. Its forage value is fair to good while young and tender. After heads mature, forage is fair for cattle and horses. As with all native range grasses, little bluestem must be managed accordingly to avoid overgrazing. Wildlife can utilize the plants and seed for food. It may also be

utilized in filter strips, field borders, contour buffer strips, and riparian forest buffers for nitrogen and phosphorous uptake, and erosion control.

3. Hondo Germplasm velvet bundleflower

   Desmanthus velutinus

   PI # 477961

   Originally collected near Hondo, Texas, velvet bundleflower is a native, perennial, warm-season legume. It is native throughout central and west Texas, and is an important component of range sites in these areas. In addition, it is valuable as a wildlife food and cover species. Velvet bundleflower may be included in CRP or EQIP plantings and range seeding mixes.

4. Cuero Germplasm purple prairie clover

   Dalea purpurea

   PI # 441183

   Originally collected near Cuero, Texas, purple prairie clover is a native, perennial, warm-season legume. It is native throughout central and west Texas, and is an important component of range sites in these areas. Purple prairie clover has high quality forage that makes the plant desirable for all classes of livestock and wildlife. It may also be included in CRP or EQIP plantings, and range seeding mixes.

Upcoming Plant Releases (3–5 years) (Year 2003 Progress Report of Activities for the James E. ‘Bud’ Smith Plant Materials Center 2004):

1. Arizona cottontop

   Digitaria californica

   Arizona cottontop is a native, perennial, warm-season bunchgrass that is common to the southwestern United States from Arizona to Colorado, south to Texas and northern Mexico. It grows best on gravelly and sandy loam soils. This grass species can be planted in pure stands or as a component in a seed mix. Possible uses of Arizona cottontop include CRP or EQIP plantings and rangeland improvement. Its forage value is good and most palatable when plants are green. It will cure well and provide adequate dry forage for cattle. It must be managed accordingly to avoid overgrazing. Wildlife can use the plants for food and cover. Selection PMT-389 Arizona cottontop was placed into the open market for production back in the late 1960s. This selection was never formally released. Plans include formally releasing PMT-389 as a select class of certified seed.

2. Giant sandreed

   Calamovilfa gigantea

   Giant sandreed is a native, perennial, warm-season rhizomatous grass that is useful in the stabilization and revegetation of sandy soils. Five accessions were selected and combined because of their similarity and overall rating for vigor, stability, abilities to spread, and seed production. The five collections composite is currently being increased and will have a new accession number of 9065015.

3. Showy menodora

   Menodora longiflora

   PI # 477967

   Originally collected near Brackettville, Texas, the Showy meonodora is a native, warm-season perennial herb or small shrub. It is native throughout west Texas and is an important component of range sites in these areas. It is valuable as wildlife food and cover species. Showy menodora may be included in CRP or EQIP plantings and range seeding mixes.

4. Havard panicum

   Panicum havardii

   Havard panicum is a tall, warm-season perennial grass with an extensive rhizome system. Eleven collections were combined and given the composite number of 9065020 and is currently undergoing a field increase.

5. Prairie acacia

   Acacia angustissima

   Prairie acacia is a native, perennial, warm-season legume. It is native throughout central and west Texas, and into Oklahoma. Prairie acacia is an important component of range sites in these areas. It is valuable as wildlife food and cover species. Prairie acacia may be included in CRP or EQIP planting and range seeding mixes. This selection of prairie acacia is a combination of 17 collections and has an accession number of 9085672.

METHODOLOGY

Seed Mixture Development

TxDOT Standard Seed Mix vs. All-Native Mix

The research team assembled alternative seed mixes comprised entirely of commercially available native plant seed (the research team decided this project was an inappropriate venue for research on seed not yet proven to be commercially viable). The team utilized established TxDOT practice of using nurse species, local adaptability, and complementary plant structure.

The seed mixtures were tested on soils representative of the general soil types (clay and sand) and pH as found in west, south, east, and north Texas (see Appendix A). The current standard mixtures used for testing were from TxDOT districts representative of the following regions: Austin (central and west Texas), Corpus Christi (south Texas), Lufkin (east Texas), and Abilene (north Texas) Districts.

The existing TxDOT seed mixture is specified in Item 164 of the Standard Specifications (2003 or latest edition) for the districts listed above (see Appendix B). The proposed native seed mixture was comprised of seed appropriate to the same districts. The planting procedures and establishment techniques were in accordance with TxDOT specifications and seeding dates.

Seed mixtures were installed with a handheld seed broadcaster except in the greenhouse, where each plot was hand seeded due to the plot size of the greenhouse plots. After each plot was seeded the surface of the soil was raked and lightly compacted in order to stimulate seed germination and growth. The normal TxDOT practice of seeding involves an approved drill-seeder, however this was not feasible in this project due to the limited size of the plots and the variation in seed types and rates for each plot.

TxDOT Standard Seed Mix 1 & 2 vs. Increased District Rates 1& 2

Seeding rate studies compared the standard TxDOT seeding rates to two increased seed rates. Table 2 shows the mixes and rates.

Table 2. Seed Mix Pure Live Seed (PLS)

<u>TxDOT Standard Seed Mix 1 (PLS) for clay soils</u>	
Green Sprangletop	0.3
Bermudagrass	2.4
Sideoats Grama (Haskell)	4.5
<u>TxDOT Standard Seed Mix 1 (PLS) for sandy soils</u>	
Green Sprangletop	0.3
Common Bermudagrass	5.4
<u>Increased District Rate 1 (PLS/acre) for clay and sand</u>	
Green Sprangletop	4.0
Sideoats Grama	3.2
Bermudagrass	26.0
Little Bluestem	1.4
Foxtail Millet	34.0
<u>TxDOT Standard Seed Mix 2 (PLS) for clay soils</u>	
Green Sprangletop	0.3
Sideoats Grama (Haskell)	7.2
Buffalograss (Texoma)	1.6
<u>TxDOT Standard Seed Mix 2 (PLS) for sandy soils</u>	
Green Sprangletop	0.3
Sideoats Grama (Haskell)	3.2
Sand Dropseed	0.3
Blue Grama (Hachita)	0.9

Table 2. Seed Mix (PLS) (continued).

Increased District Rate 2 (PLS/acre) for clay and sand	
Buffalograss (Texoma)	110.0
Common Bermudagrass	110.0
Tall Fescue	110.0

Trial Locations

- Researchers conducted outdoor field trials (using TxDOT standard seed mixtures of the Austin, Abilene, Lufkin, Corpus Christi, Houston, and San Angelo districts) were conducted at the Hydraulic and Erosion Control Laboratory (HSECL).
- One roadside demonstration trial was conducted in Georgetown, Texas, to better replicate the unique soil conditions of the central Texas region.
- Six greenhouse trials were conducted at the HSECL on each seed mixture for control/comparison with outdoor trials. These included tests on clay and sand from Austin, Abilene, Lufkin, Corpus Christi, Houston, and San Angelo districts.
- One greenhouse trial was also conducted at the HSECL to compare a cool season all native seed mix with the TxDOT standard cool season mix for the Lufkin District. These trials were conducted on both clay and sand soils from the Lufkin District.

Experiment Design

- The outdoor trials were a randomized plot design of each soil type with three replications. This resulted in 12 plots per trial. Each seed mixture was installed on six 10-foot x 10-foot (10'x10') plots (three sand soils and three clay soils). The plot for each seeding replication was randomly assigned.
- Greenhouse trials were single 4-foot x 4-foot (4'x4') plots of each mixture being tested with two replications. These plots were not drill-seeded. Seeding followed standard HSECL procedures.

- Soil was imported from each target region to replicate the regional soil type as closely as possible (see Appendix A). The soils were installed in excavated trenches to a depth of 12 inches and brought to grade. The cleanest soil available was attained, and no herbicides or sterilization were used in preparing the test plots.
- One-half of each trial plot was mowed to a height of 6-8 inches on four occasions: November 2004, July 2005, November 2005, and July 2006.

Data Collection

- Irrigation was applied in the greenhouse based on the annual total rainfall for the various locations from where the soil was obtained.
- Outdoor plots were not irrigated or provided with any supplemental irrigation; however detailed precipitation and temperature data was recorded for the outdoor plots during the duration of this project.
- Total percent vegetation cover (V-Cap) was determined at 60 days, 90 days, 120 days, and 12 months, after installation (total percent cover).
- Individual species height and overall plot height (inches to highest plant part) of each side of the plot (mowed and un-mowed) was recorded and monitored regularly as well as individual species height for both the native introduced and non-planted species present on the plots. This measurement was completed prior to mowing the plots.
- Individual species cover was recorded regularly during the project. This data was documented and recorded on the following occasions: November 2004, April 2005, August 2005, October 2005, and June 2006.
- All plots were photographically documented at the time of installation and at each data-collection period.
- Collected data was evaluated for statistical significance using appropriate analysis-of-variance techniques.

Figures 1, 2 and 3 below show the plots during the testing period.

Figure 1. Outdoor Plot Preparation.

Figure 2. Early Vegetation on Greenhouse Test Plots.

Figure 3. Georgetown Demonstration Test Plots.

Compost Derived Fertilizer Leachate Study

Improving soil nutrient content in impoverished soils will encourage a quicker vegetative cover. The rate of nutrient loading should be a balance between the amount of nutrient applied to the site and the amount that plants can take up within a given period. However, an increase in nutrient levels beyond that needed for successful establishment may result in nutrients leaching from the site into adjacent water bodies. While eutrophication is a natural aging process of water bodies, human activities can accelerate the process by adding nutrients from over-application of fertilizers, particularly nitrates and phosphates.

One of the main problems caused by nutrient over-loading in water bodies is algal bloom, typically caused by excess phosphate accumulation. Algal blooms often lead to oxygen depletion and result in fish and vegetation death. Nutrient over-loading could also involve added costs to mitigate the problems. In addition, project costs could increase due to the need for added mowing later on due to increased grass growth.

Large areas such as rights-of-way are considered a non-point source for runoff of specific elements. Non-point source means that the area is too large and diffuse to identify a specific point where it accumulates and exits a site. This is in direct contrast to things such as pipes carrying waste from a plant or swales carrying runoff from feedlots. Non-point sources are difficult to regulate and may even vary throughout time. Leaching of nutrients from the soil due to rainfall is a typical non-point source mechanism.

Leaching of nutrients through the soil may be moderated by using time-released fertilizers which will allow the nutrients to remain available to the vegetation for a longer period of time as opposed to quickly being used by plants or excess rainfall immediately after application. The chemical properties of organic content also slow leaching. Nutrients easily and tightly bond to organic molecules, making them more accessible to plants and preventing their rapid movement through the soil.

Soil nutrient resources affect the amount of vegetative biomass (plant cover) that develops within a given period of time. Applying these nutrients at high rates may result in greater plant cover in a shorter period of time but may also increase nutrient loading that, depending on soil structure, organic content, slope, and rainfall amounts, may leave the site before being accessed by the plant material. This project examined a set of modified nutrient sources and application rates to compare the effects on plant cover rates and nutrient leaching in a specific condition.

TxDOT Standard Fertilizer Rate (TxDOT Specifications for Construction and Maintenance of Highways, Streets, and Bridges, Item 166.2.) specifies a complete fertilizer containing nitrogen (N), phosphoric acid (P), and potash (K) unless otherwise specified on the plans. At least 50 percent of the nitrogen component must be of a slow-release formulation such as a urea-based and plastic resin-coated fertilizer. The standard TxDOT rate is 100 lb/acre of nitrogen. This study looked at the following fertilizer/compost applications:

- 13-13-13 TxDOT Standard Fertilizer Formulation
    - Applied at 300 lb/acre (39 lb Nitrogen/acre)
- 23-0-3 TxDOT Standard Fertilizer Formulation
    - Applied at 100 lb/acre (23 lb Nitrogen/acre)
- 6-3-0 Organic Compost-derived Fertilizer
    - Houactinite surface-applied at 4000 lb/acre (240 lb Nitrogen/acre)
    - Compost: 1 inch tilled into top 4 inches of soil

Houactinite is an organic, granular fertilizer produced as a bulk, bio-solid product by the City of Houston, Texas since the 1920s. The compost used in this study was approved for use by TxDOT as general compost, meaning that it came from an STA Certified compost facility and had passed all required physical requirements based on the Compost Technical Data Sheets which accompanied the compost delivery. The compost was supplied by Living Earth Technologies and was representative of the compost used in the Houston District.

Figure 4. Compost Leachate Test Flume.

TEST PROCEDURES

The leachate tests were performed in a concrete block wall test flume located at the TxDOT/TTI HSECL located on the Riverside Campus of Texas A&M University. The test flume dimensions were 10-feet wide x 60-feet long and contained a clay slope of 3 percent. Rainfall was applied uniformly over the test flume at a rate of 1 inch/hour with a 4-hour duration. Water samples were collected at 2, 2.5, 3.5, and 4 hours after rainfall was initiated. Each of the water samples was obtained by sampling "stream flow" water as it was running off of the surface of the soil in the test facility. Water samples were taken immediately downstream of the test facility so that water quality could be determined at that point. Soil samples were also taken before and after each of the test runs. Both water and soil samples were sent to the Texas A&M Soil Water and Forage Testing Laboratory and examined for a variety of properties and components.

IMPLEMENTATION

The results of this project will be implemented into the TxDOT Standard Specifications for use in vegetation establishment, Item 164, Seeding for Erosion Control.

This project includes guidance and recommendation on the use of native plant species for vegetation establishment. This guidance includes lists and descriptions of the species currently available in the industry, the different forms of native plants and their potential application, installation and establishment issues, the nature of native plant communities, and their role in environmental quality.

The results of this research will enable TxDOT to develop additional tools to meet expanding needs in roadside vegetation establishment. The results of the study will indicate the feasibility of using a seed mixture comprised entirely of native plant species. A pure native seed mixture may prove more adaptable in specific local conditions and possibly lead to a reduction in long-term care needs such as mowing or weed control. Such reductions may improve the cost-effectiveness of vegetation establishment over the life of the project.

This project will enable TxDOT to determine if the established standard seed mix rate is successful at establishing permanent vegetative cover at the most economical rate or if the standard rate needs to be increased to achieve the necessary cover.

As mentioned earlier, the aesthetic component of native vegetation is not an insignificant issue as more and more people desire to see their roadways be more reflective of the natural heritage of the area. Accomplishing this goal requires coordination across disciplines within TxDOT as provided in TxDOT's On-line Design Manual. The Landscape and Aesthetics Design section of this manual provides an introduction to the issues of the use of vegetation and landform in roadway design, both from a management as well as aesthetic point of view. This information is referenced in the manual in the following locations:

- Chapter 3, Section 2, Item 2370, "Prepare Assessment of Landscape and Aesthetic Issues," specifically addresses identifying landscape and aesthetic issues to be addressed as part of a project and recognizes that in some cases, these will overlap with environmental concerns.
- Chapter 3, Section 3, Item 3350, "Prepare Landscape Recommendation," includes "selective clearing and thinning" as part of its goal of "blend[ing] the project with adjacent land use[s]."
- Chapter 4, Section 5, "Blend the Highway," speaks very specifically to this issue through the use of similar plant material [implies saving existing plant material] and using exposed rock faces and landforms as aesthetic elements. The On-line Design Manual also mirrors the stated goal of this project regarding cost issues when it states: "Dealing with these issues early in the design process will avoid costly aesthetic remediation activities later."
- Chapter 5, Section 5, "Highway and Transportation Corridors," makes specific reference to the importance of landmarks, changes in topography, already occurring vegetation, and how these may be incorporated into a project.

In September of 2003, TxDOT initiated a project, RMC Project 0-4548: "Minimizing the Impacts to Existing Vegetation and Sensitive Landforms during Roadway Construction" in support of these issues. The project was developed to provide TxDOT designers and project managers with specific information that would allow them to assess the factors at issue with protecting and preserving trees and other plant material (specifically established native plants) in the roadway. The project now under consideration is directly supportive of all of these goals, particularly project 0-4548, since the end result is to help TxDOT to be more effective and cost-efficient in its efforts to be more environmentally proactive in its programs.

RESULTS/OBSERVATIONS

All the raw data is included in the appendices of the report. For readability purposes, figures were the primary format used in the main text of this chapter. A detailed breakdown of species in each test condition was also presented in the appendices.

Standard vs. Native Seed Mix

Abilene Region

In outdoor clay plots, standard seed mix seems to perform better than native seed mix at all observation times except for the last data collected in October 2005. At 150 days after planting (near November 2004), both seed mixes showed good mean coverage above 70 percent. It should be noted that although the V-cap coverage of both seed mixes were similar, the authors found that the vegetation coverage contributed by planted and non-planted species was very different. As shown in Figures 1 and 2, the standard seed mix has 43 percent non-planted coverage while the native seed mix has 86 percent. Detailed breakdown of species can be found in Appendix C. In the final data the planted coverage of the native mix was equally divided between Illinois Bundleflower and Sideoats Grama with approximately 5 percent each. In the standard mix, Green Sprangletop germinated quickly yet diminished as the project progressed indicating its ability to act as a nurse grass. On the other hand, Sideoats Grama improved throughout the project and was the dominant species (see Appendix C, page C-8).

In outdoor sand plots, both the native and standard seed mixes show very similar V-cap performance throughout the entire monitoring period with final total vegetative cover exceeding

97 percent . No distinct difference in planted vs. non-planted species was observed. Both seed mixes show very similar vegetation coverage composition between planted and non-planted species. In the native mix Sideoats Grama and Illinois Bundleflower made up the majority of the vegetation with a very small amount of Partridge Pea and Englemann Daisy. In the standard mix, Green Sprangletop and Weeping Lovegrass made up the majority of this mix along with a small amount of Sand Dropseed and Green Sprangletop (see Appendix C, page C-10).

In indoor clay plots, V-cap performance of both standard and native seed mixes was not as good as what was observed outdoors. Native seed mix does not even cover 50 percent 400 days after planting (October 2005), showing large variance between plots by times. Standard seed mix also has less than 40 percent of mean coverage before 150 days after planting. Overall, it can be concluded that standard seed mix shows greater performance than native seed mix at all observed times. Another observation of interest to the authors is that the planted vegetation coverage of both seed mixes increased quicker than non-planted species early on but declined toward the end of the monitoring period. At approximately midway through the project (June 2005) the native mix established a high of 30 percent planted cover. This amount was nearly equally divided between Sideoats Grama, Engelmann Daisy, Illinois Bundleflower and Partridge Pea. However, at the end of the project the native mix reduced to approximately 11 percent with only Sideoats Grama and Illinois Bundleflower remaining. The standard mix produced a final cover of 19 percent, which was mostly made up of Sideoats Grama which steadily increased throughout the project. Green Sprangletop established quickly with approximately 25 percent but diminished as the project progressed and ended with less than 5 percent (see Appendix C, page C-4).

In indoor sand plots, as presented in Figures 7 and 8, they appear to be similar to outdoor sand plots. The V-cap performance of standard seed mix is analogous to that of native seed mix except for 60 days after planting. Both seed mixes show good performance shortly after planting: 81 percent for standard seed mix and 96 percent for native seed mix at 60 days. In addition, most vegetation coverage at the end of the monitoring period was contributed by non-planted species: 82 percent in the standard seed mix plot and 97 percent in the native plot indicating that only 3 percent was a result of the planted, native mix. This small percentage was made up of Partridge Pea and Illinois Bundleflower. The standard mix produced an initial cover of nearly 50 percent which was made up of approximately 40 percent Green Sprangletop and 10 percent Sand Dropseed. This standard rate diminished to 17 percent at the end of the evaluation period. Again, the Green Sprangletop started strong but was greatly reduced at the end of the project while Sand Dropseed remained a constant 10 percent throughout. At the beginning of the second year, Weeping Lovegrass began to establish and ended with approximately 5 percent (see Appendix C, page C-6).

In summary, no significant statistical difference in overall performance was observed. The non-planted species seem to become the dominant species either at the early stage or toward the end of the monitoring period. Of the planted species, researchers identified several trends. Sideoats Grama and Illinois Bundleflower were the two dominant species in the native seed mix. In the standard mix, Green Sprangletop started strong but rapidly diminished and was almost non-existent at the end of the project in each of the test plots. Sideoats Grama steadily increased in each of the clay test plots. Sand Dropseed and Weeping Lovegrass were the only two other species which produced in any significant quantities on the clay plots.

Austin Region

In outdoor clay plots, both standard and native seed mixes had very similar V-cap performance. The major difference observed by the researchers is the contributors to the vegetation coverage. At the end of the monitoring period, 90 percent of the vegetation coverage was from planted species in the standard mix whereas only 31 percent was from the planted species in the native seed mix. Detailed breakdown of species can be found in the appendices. Of the 90 percent final cover for the standard mix, Common Bermudagrass made up more than half of that amount. Green Sprangletop established strong early in the project but diminished as the project progressed. Sideoats Grama remained at a steady 20 percent throughout the entire project. In the native mix Green Sprangletop established early in the project at a rate of almost 50 percent but diminished as the project progressed. Sideoats Grama increased steadily and ended with almost 20 percent coverage. In both mixes, Illinois Bundleflower finished with approximately 5 percent (see Appendix C, page C-16).

In outdoor sand plots, similar V-cap performance between both seed mixes was also observed. In this experiment, non-planted species were able to dominate the vegetation coverage on both seed mixes early on, but the planted species on the standard seed mix plot was able to outperform the non-planted species toward the end of the monitoring period. In the standard mix Common Bermudagrass accounted for approximately 65 percent while Weeping Lovegrass, Green Sprangletop, and Partridge Pea accounted for the remaining 13 percent. As in other test applications, Green Sprangletop diminished as the project progressed. While the native mix ended with a final planted coverage of 27 percent, it produced a higher percentage (30 percent) earlier in the project. Of this mix, Illinois Bundleflower and Sideoats Grama produced the majority of the planted native mix (see Appendix C, page C-18).

In indoor clay plots, standard seed mix show a quicker vegetation establishment than the native seed mix, but both reached near 100 percent at the end of the monitoring period. It should be pointed out again that the planted species in both seed mixes established quicker than non-planted species and declined toward the end of the monitoring period. The planted species on the standard seed mix plots were able to maintain higher percent cover vegetation than non-planted species at the end. At the approximate midpoint of the project, the standard mix established 100 percent coverage with most of the vegetation a mix of Common Bermudagrass and Green Sprangletop. This standard mix coverage diminished to less than 60 percent at the end of the project with the same two dominant species. The native mix started out with an early reading of approximately 50 percent but diminished gradually throughout the project ending with a planted species cover of less than 30 percent. Sand Lovegrass and Sideoats Grama made up all but a very small percentage of this final cover as Illinois Bundleflower accounted for less than 5 percent (see Appendix C, page C-12).

In indoor sand plots, both seed mixes show similar overall V-cap performance. The difference between them is that the planted species of the standard seed mix dominated the plots throughout the entire monitoring period, whereas the result was opposite on the native seed mix plots. The standard mix produced almost 100 percent total vegetative cover with approximately 60 percent consisting of Weeping Lovegrass. At the end of the project there was a very small amount of Common Bermudagrass and Sand Lovegrass. While the native mix produced a smaller amount of total vegetative cover, it did produce a higher number of planted species. This mix produced approximately 20 percent Illinois Bundleflower and almost equal amounts of Sideoats Grama, Green Sprangletop, and Englemann Daisy (see Appendix C, page C-14).

In summary, the overall V-cap performance was similar regardless of the seed mix or the soil type. However, a significant difference in whether the vegetation coverage was contributed by the planted species in the seed mix was observed. The planted species on the standard seed mix plots appears to maintain its dominance on the plots, compared with the opposite observation on the native seed mix plots. Overall, the dominant species from the native mix planted on the clay plots was Green Sprangletop which started strong but diminished as the project progressed while Sideoats Grama increased over time. The standard mix produced nearly three times the total vegetative cover as the native mix on the clay plots with Common Bermudagrass and Sideoats Grama being the dominant species (see Appendix C, page C-16).

Corpus Christi

In outdoor clay plots, overall V-cap performance was similar on both seed mix plots. Despite the similar overall performance, the dominant species on the vegetation coverage was very different. Similarly to some of what was observed in the Abilene and Austin plots, the planted species of the standard seed mix was able to outperform the non-planted species toward the end of the monitoring period. However, the non-planted species in the native seed mix plots dominate throughout the entire experiment. The native seed mix was almost evenly divided between Plains Bristlegrass and Illinois Bundleflower. Again, Green Sprangletop started strong but almost disappeared by the end of the project. Over 60 percent of the final cover for the standard mix was Common Bermudagrass. Plains Bristlegrass accounted for approximately 40 percent early in the project but diminished to approximately 15 percent by the end (see Appendix C, page C-24).

In outdoor sand plots, V-cap performance of standard seed mix was quite similar to that of native seed mix at all observation times after planting. The planted species of the standard seed mix dominated throughout the entire period, while the planted species of the native seed mix led early but declined to slightly less than the non-planted species at the end. The standard mix on the outdoor sand plots produced the greatest percent overall cover of a single species in the entire project. Common Bermudagrass was the single species identified in the overall 87 percent total cover. Early in the project Green Sprangletop and Common Buffelgrass established on the test plots but were soon overtaken by the growth of the Common Bermudagrass. The native mix, however, produced a smaller total vegetative cover of only 45 percent consisting of almost equal amounts of Partridge Pea, Illinois Bundleflower, and Sideoats Grama (see Appendix C, page C-26).

In indoor clay plots, V-cap performance and the composition percentage between planted and non-planted species were all similar on both standard and native seed mixes. Both mixes performed poorly on the indoor clay plots with neither producing more than 19 percent total vegetative cover. While both Plains Bristlegrass and Illinois Bundleflower produced in both mixes, Common Bermudagrass was the dominant species and showed up only in the standard mix (see Appendix C, page C-20).

In indoor sand plots, V-cap overall performance on both standard and native seed mixes was similar at 98 to 99 percent respectively. The composition percentage between planted and non-planted species observed at the end of the period was also similar for both seed mixes. The only difference observed was that only planted species of the standard seed mix showed up at the early stage but were quickly outperformed by non-planted ones at the later stage. The final planted cover for the native mix was almost equally divided between Illinois Bundleflower and Sideoats Grama. However, the desired planted cover for the standard mix was made up almost entirely of Common Bermudagrass which started out very strong but diminished as the project progressed and the non-planted species began to take over the plot (see Appendix C, page C-22).

In summary, vegetation coverage in the Corpus Christi trials reached near 100 percent very quickly regardless of seed mix or soil type. In the outdoor conditions, planted species of the standard seed mix dominated whereas non-planted species on the native plots dominated. In the indoor conditions, non-planted species dominated on both seed mixes. Plains Bristlegrass and Common Bermudagrass were the dominant species in the clay plots. Illinois Bundleflower was present in most clay plots in small quantities as well. On the sand plots, Common Bermuda and

Green Sprangletop were the species which produced the most vegetation. As it was with the clay plots, Illinois Bundleflower was present in small quantities on most sand plots.

Lufkin Region

In outdoor clay plots, the overall V-cap performance of both seed mixes was similar at the early stage but gradually differed toward the end of the monitoring period. Native plots (99 percent) were somehow higher than the standard plots (88 percent). Both mixes produced well on the outdoor clay plots. The native mix ended with a final total vegetative cover of more than 81 percent with Partridge Pea comprising almost 50 percent of the final cover. Sideoats Grama produced slightly more than 20 percent while Green Sprangletop, Illinois Bundleflower, and Bushy Bluestem accounted for the remainder. The standard mix produced slightly more total vegetative cover at 87.91 percent with Common Bermudagrass and Sideoats Grama making up almost 75 percent of the total. Bahiagrass, Green Sprangletop, and Illinois Bundleflower also established on the test plots in small quantities (see Appendix C, page C-40).

In outdoor sand plots, the overall V-cap performance of both seed mixes was similar throughout the entire experiment. The major difference observed at the end of the monitoring period was the contribution of planted species on the vegetation coverage. The planted species of the standard seed mix had 89 percent coverage while the native species only had 48 percent. The standard mix produced an excellent cover of Common Bermudagrass with 89 percent coverage. No other species were identified on these test plots at the end of the project. The native mix produced a variety of vegetation consisting mostly of Green Sprangletop, Partridge Pea, and Bushy Bluestem, although its overall establishment was only 48.17 percent (see Appendix C, page C-42).

In indoor clay plots, the overall V-cap performance was quite different in the middle of the monitoring period but became similar toward the end. The standard seed mix was able to establish vegetation quicker than the native mixes at the early stages. The planted species of the standard seed mix was the primary contributor to the vegetation coverage at the early and middle stages of the monitoring period but declined significantly to be only slightly greater than the non-planted species at the end of the project. The native mix produced its highest overall vegetative cover in June 2005 and diminished to 37 percent at the end of the project. Of this final percent cover, Sideoats Grama was the dominant species with Green Sprangletop, Partridge Pea, Sand Lovegrass, and Englemann Daisy all contributing equally. Common Bermudagrass was the dominant species in the standard mix throughout most of the project but diminished at the end allowing Bahiagrass to produce the most vegetation (see Appendix C, page C-36).

In indoor sand plots, the overall V-cap performance was very similar on both seed mixes. Also, the composition ratio between planted and non-planted species was similar for both seed mixes at the end of the monitoring period. Bushy Bluestem accounted for approximately 75 percent of the final native mix coverage. Sideoats Grama and Englemann Daisy made up the remaining 25 percent. Of the final 42.75 percent produced by the standard mix, Common Bermudagrass produced the most vegetation by far, with Green Sprangletop accounting for less than 2 percent (see Appendix C, page C-38).

In summary, similar overall V-cap performance was observed on all conditions except the early stage of the indoor clay plots. Although there were many species which produced on the clay plots, Green Sprangletop and Common Bermudagrass were the dominant species accounting for most of the vegetation produced on these plots. Common Bermudagrass and Green Sprangletop were also the most dominant on the sand plots although the total number of species present was much lower.

Georgetown

As shown in Figures 3 and 4, the overall V-cap performance of both seed mixes was very similar with 100 percent coverage. There was only a sight difference between the planted species' coverage of each seed mix: 74 percent and 63 percent for the standard and native mixes, respectively. In the native mix, Illinois Bundleflower and Sideoats Grama were the dominant species, while Common Bermudagrass and Green Sprangletop were the dominant species in the standard mix. Small quantities of Blue Grama were present in both standard and native seed mix plots (see Appendix C, page C-28).

Lufkin Region (Cool Season)

During the development of the project, the research committee decided to test a cool season seed mix. It was decided to use the Lufkin region characteristics on indoor test plots for this evaluation. This cool season mix was successful in that it produced more than 90 percent total vegetation cover in all but one test application. The native seed mix produced 97.25 percent and 94.00 percent cover on the indoor clay and sand plots, respectively. Of these percentages Orchardgrass was the single species which germinated and established on the test plots. Texas Winterbrush and Bottlebrush Squirreltail were also planted but never identified on the test plots. On the indoor test plots, the standard mix established an overall vegetative cover of 100 percent and 75.5 percent on the sand and clay plots, respectively. Of this percentage Oats comprised 80 percent of the total cover on the sand plots and 60 percent on the clay plots. Again, these test plots produced a single species at the end of the project although Winter Wheat and Tall Fescue were planted at the beginning of the project (see Appendix C, pages C-47, 48).

Standard TxDOT Seed Mixes 1 & 2 vs. Increased District Rates 1 & 2

The Increased District Rate trials focused on two different increased rate seed mixes and compared them to two different standard TxDOT seed rates. Both clay and sand were used for the experiment. For ease of reading, the Increased District Rates 1 & 2 are referred to as “district” while TxDOT Standard Seed Mix is referred to as “standard.”

Increased District Rate 1

In outdoor clay plots, both standard and district seed mixes showed very poor performance at the first half of the monitoring period (almost four months), only 3 percent and 6 percent vegetation coverage was observed for standard and district seed mix, respectively, even at 160 days after planting. This lack of performance may well be attributed to the timing of the initial seeding in October when it is almost the end of the growing season. The major V-cap performance difference occurred towards the end of the monitoring period. District seed mix produced a much higher vegetation coverage (98 percent) than that (31 percent) produced by standard seed mix. In addition, the major contributor to the vegetation coverage was also different. The district test plots were dominated by planted species (94 out of 95 percent) whereas the standard test plots were dominated by non-planted species (24 out of 31 percent) (see Appendix C, page C-33).

In outdoor sand plots, no significant statistical difference in performance was observed. Also, the ratio between planted and non-planted species on both seed mixes was similar. It should be noted that almost all the vegetation coverage on outdoor sand plots resulted from non-planted species (see Appendix C, page C-34).

In indoor clay plots, district seed mix seemed to perform better than the standard seed mix. However, this observation was statistically insignificant. Nonetheless, both seed mixes yielded a similar vegetation growth pattern. At the early stage, both mixes started vegetation slowly and eventually increased to higher values. This performance could also be attributed to the initial seeding time in October and to the indoor test conditions in the greenhouses which were not a complete simulation of growing seasons (see Appendix C, pages C-30, 31).

In indoor sand plots, the overall V-cap performance was very similar for both seed mixes. When compared with the results of the outdoor sand plots, a similar result was also observed in that almost all of the vegetation coverage resulted from non-planted species. It was inferred that the sand soil imported from the District may have contained seeds that produced the non-planted vegetation (see Appendix C, pages C-30, 31).

In summary, the seeding time for the Increased District Rate 1 trial occurred at the end of a growing season which appears to affect the vegetation establishment rate in the beginning. Vegetation coverage on sand plots (both outdoor and indoor) resulted almost exclusively from non-planted species. These data suggest that sands imported from the District may have contained a high amount of seeds that produced vegetation not included in both Standard and District seed mixes.

Increased District Seed Mix 2

In outdoor clay plots, both Standard and District seed mix showed poor performance, with less than 40 percent coverage during the entire experiment. As in the Increased District Rate 1 trials, the seeding time for the Increased District Rate 2 trials was also late in the growing season. Hence, slower vegetation establishment in the beginning was caused by the seeding time. The district seed mix seemed to outperform the standard mix, as the vegetation coverage was 39 percent for the district and 10 percent for the standard. The major contributor to the vegetation cover differed between the district and standard mixes—planted species for the district plots (30 out of 39 percent) and non-planted species (9 out of 10 percent) for the standard plots (see Appendix C, page C-44).

In indoor clay plots, District seed mix also outperformed the standard seed mix. The vegetation coverage for the District mix was 69 percent while the Standard mix was 12 percent at the end of the monitoring period. Also, the major contributor to the vegetation cover was—planted species for the district plots was 65 out of 69 percent while non-planted species was 11 out of 12 percent for the standard plots (see Appendix C, page C-45).

CONCLUSIONS

TxDOT Standard Mix vs. All-Native Seed Mix

The vegetation cover was slightly higher for the standard mix than for the native mix. The rate of germination was also slightly higher for the standard mix. These variances were relatively small, leading to the conclusion that there is no significant statistical difference.

TxDOT Standard Seed Mix vs. Increased District Rate 1

There was no significant statistical difference in vegetation cover between the Standard Seed Mix and the Increased District Rate 1 mix except for the outdoor clay test plots. A higher percentage of non-planted species were found on the Standard Seed Mix plots.

TxDOT Standard Seed Mix vs. Increased District Rate 2

There was a statistical difference between the vegetation cover for the Increased District Rate 2 and the Standard Seed Mix, as the Increased District Rate 2 established more vegetation than the

Standard Seed Mix on both indoor and outdoor clay test plots (69 percent to 12 percent and 39 percent to 10 percent, respectively). There was also a higher rate of non-planted species found on the Standard Seed Mix plots.

DISCUSSION

General Vegetation Observations

Green Sprangletop quickly established early in the project but consistently declined as the project progressed. Very little Green Sprangletop was present at the end of project. Quick establishment characterizes its use as a nurse plant in seeding programs. Bermudagrass established rapidly (even when not planted in many of the native plots). It may have been present in the soils before delivery to the site. On the un-mowed plots, Bermudagrass began to choke itself out while it grew vigorously on the mowed plots. On the other hand, Bushy Bluestem performed well on the un-mowed plots but declined under mowing. Illinois Bundleflower established well and produced good cover. Sideoats Grama and Weeping Lovegrass consistently increased in percent coverage throughout the project. Englemann Daisy was slow to get started but grew well in the late spring and early summer. Partridge Pea established itself on the clay plots early on in the project but declined rapidly on both the mowed and un-mowed sections. Species showing the most vigorous growth were Green Sprangletop, Sideoats Grama, Common Bermuda, Weeping Lovegrass, Partridge Pea, Illinois Bundleflower, Plains Bristlegrass, Sand Lovegrass, Englemann Daisy, and Orchardgrass (cool season). The most common non-planted (voluntary) species were Johnsongrass, Ragweed, Texas Thistle, Sunflower, Morning Glory, Black Nightshade, Goosegrass, and Little Barley.

Figure 5. Testing the Effects of Mowing.

Mowing Effect

The amount of non-planted species diminished on the mowed areas while planted species increased. Partridge Pea and Bushy Bluestem decreased significantly or were completely eliminated by mowing. Common Bermudagrass and Sideoats Grama proved to be more vigorous on the mowed plots. Annual weeds (particularly Bloodweed, Ragweed, and Sunflower) decreased significantly when mowed. Weeping Lovegrass, Sand Lovegrass, and Englemann Daisy showed very little difference on the mowed and un-mowed sections (Figure 5). Interestingly, Little Bluestem showed increased growth toward the end of the project, however it was only present on the un-mowed side of the plots As mentioned earlier, the dense cover of un-mowed Bermudagrass began to thin and start to decline toward the end of the project.

Greenhouse and Outdoor Test Plot Differences

Plant species that did well outdoors generally did well in the greenhouse plots with the exception of Bermudagrass and Bahiagrass. Bermudagrass at first showed good growth characteristics in the greenhouse but for unknown reasons declined quickly. Bahiagrass, on the other hand, showed considerably more growth in the greenhouse than on the outdoor plots. The difference in vegetation establishment rates in the indoor versus the outdoor plots was a surprise. The reason for this difference is not conclusive. The light variation due to the cover type of the greenhouse (clear vinyl) may have been just enough to retard growth. The humidity levels in the greenhouse, even though the house is ventilated, may have affected growth. The planted soils in the greenhouse were twelve inches deep in raised boxes sitting on concrete. This was considered ample for the duration of the study. However, temperature variations in the soil due to these conditions may have been too out-of-sync with the natural sequence soil temperatures. No soil temperatures were taken. It may have been possible that soils may have experienced too much daily fluctuation during the winter; warm during the day and cool or cold at night. Soil temperatures in the outdoor plots would have likely been more consistent on a daily basis. Since comparisons between the standard mix and the native mix show the same general relation in percent of vegetation establishment it is likely that difference between the outdoor and indoor plots were due to the differences in growing conditions rather that seed mix.

Diversity of Roadside Vegetation

It may be fairly observed that some may assume (perhaps more implicitly that explicitly stated) that the character of a restored vegetative community will, in the long term, be largely determined by the composition of the initial seeding or sprigging. If this assumption of the vegetative community is true, the initial seed mix is of critical importance, if not then the role of the initial seeding must be re-described.

The goal of vegetation studies, whether they are for roadsides or for restoration of sensitive habitats, is to enable designers and managers to predict with greater certainty what will happen if certain practices are instituted. It is relatively easy to estimate the short-term impacts of specific management practices. Widening the scope to include more variables greatly reduces our predictive power. These variables include adjacent plant communities, wind-born seed, animal-introduced seed, the transfer effect of vehicles, the existing soil seed bank, orientation, slope, soil pH, permeability, seasonal climate variation, variation in soil nutrients, species competition, unplanned disturbance, planned disturbance, and more.

While the initial steps taken in rehabilitating a site are important short-term activities, long-term development will be determined by factors that cannot be predicted or foreseen with any significant degree of certainty.

The observations presented here should be considered informal. Making a characterization for the whole state based on so few observations is insufficient to draw definite conclusions that will be applicable everywhere. Clearly, however, roadsides older than a few years commonly hold many more species and greater diversity than was seeded or suspected. More study is needed to determine how long-term roadside vegetation development might influence the design decisions we make in the early stages.

Topsoil/Organic Content

Typically, soils best suited for highway construction are soils which compact densely to support the loads of roads and structures, limit water intrusion into the soil, and resist dislodgement through erosion. While these attributes are excellent engineering properties, these soils are basically sterile, lacking the nutrients necessary to promote the long-term establishment of vegetation. These compacted soils do not allow moisture, nutrients, or oxygen to be made available to the plant. The likelihood that seeds will germinate and send roots into this compacted soil is slim.

When the thin layer of topsoil is removed during highway construction (i.e., cut/fill operations) these exposed sub-soils will not fully re-vegetate if left in this condition. The angle of these slopes will cause any surface moisture to run off quickly, causing erosion and compounding the problem of establishing vegetation.

While there are several factors which indicate a soil's ability to establish vegetation (i.e., pH, and basic soil nutrients of nitrogen, phosphorus, potassium [N-P-K]), the soil's organic content (OC) is one of the most crucial factors. Soil organic content affects the internal structure of the soil that enables roots, moisture and nutrients suitable conditions for their interactions.

Soil organic content is derived from a variety of sources including decomposed plant tissue. Leaves and roots of plants and trees as well as grasses supply large quantities of organic residue. As these organic materials decompose, they are digested by soil organisms, which contribute residue that helps create a stable condition for maintaining a soil's organic content. Animals also play a role in this process. As they digest vegetation they contribute waste products which, through a chemical and physical process, enhance the organic content of a soil. Healthy grasslands will have an OC range of 2 – 6 percent. While this percentage may appear small, OC plays a vital role in plant nutrition and in meeting photosynthesis requirements necessary for seed germination and plant growth. Soils low in OC will support vegetation if other soil conditions are suitable but establishment is much slower. This difference is because soils high in OC retain moisture longer, enabling vegetation to withstand periods of drought.

Benefits of OC include:

- moisture-holding capabilities – making moisture available to seed and plant – as high as 60-90 percent,
- temperature protection – protection from both high and low temperatures,
- nutrient availability – nutrient-holding capacity making them available to the plant,
- native seed bed – most topsoil includes a natural seed bed which helps establish vegetative cover,
- increase surface roughness – due to the rough surface the storm water will move at a reduced rate,
- soil particle binding capabilities help reduce erosion, and
- increased Cation exchange – allows absorption of nutrients.

Temperature and precipitation are major influences of organic content in soil. This assessment explains why the soils in the Eastern TxDOT districts where rainfall is high and temperatures are relatively low (i.e., Beaumont, Houston, Lufkin) tend to have a higher organic content than the Western Districts (i.e., El Paso, Midland).

Topsoil is that area of the soil column comprising the surface of the soil. The depth of topsoil varies depending on the parent soil material, rainfall, and soil character (clay, sand, etc.). In some cases, depth may be only a few inches or even less. In other cases, topsoil may extend to as much as three feet or more. For purposes of convenience and consistency, one way of determining soil depth is by the presence of plant parts such as roots and accumulated plant litter within the soil.

Topsoil with actively growing plants typically contains the organic content and other favorable attributes of good soil structure. Nutrients may still be low in one or more category, but if plants are actively growing in a soil then the minimum basic structure is likely in place. The best topsoils are those that allow water infiltration, enable easy root penetration, and have moisture-holding capabilities. Soils with a high sand content, a small amount of clay or silt, and the presence of organic content are the best. These soils are referred to as sandy-loam and silt-loam. Clay-loam soils are also very suitable if they exist in place but are difficult to spread evenly with equipment.

The most economical method of obtaining topsoil is to strip and stockpile from the right-of-way for later use on the job. However, this is not always possible since topsoil may not exist on every jobsite. In this case the topsoil should be obtained through approved sources. Current TxDOT Specification Item 160 indicates that topsoil obtained from outside the row must have a pH of 5.5 to 8.5. This balance can easily be established with a basic soil test. Organic content can and should also be tested to help determine how much additional organic material may be needed to improve the soil structure.

Seeding Discussion

The commonly cited NRCS standard for rangeland seeding is 20 pure live seeds (PLS) per square foot. For poor soils or severe climatic conditions a “critical rate” is suggested at 40 PLS per square foot. These seeding rates for rangelands and pastures were developed so long ago that attributing them to a specific study may not be possible. One of the reasons for these rates expressed by NRCS staff was that the goal of rangeland seeding is not to establish quick vegetative cover but rather to establish a presence that will, in time, develop into a vegetation community. Budget was also considered a strong rationale since even small amounts of seed over large acreages can result in high seeding costs, particularly for native grasses.

Some NRCS agronomists feel that 20 seeds per square foot is too low for many species including Bermudagrass and many native grass species as well. Some of the Plant Materials Centers are hoping to conduct seeding trials to set a more definitive rate for Bermudagrass in the future, but at this time, the established rates mentioned above are still used as a baseline figure.

The NRCS staff interviewed believed that too much seed at the time of planting may be detrimental in one of two ways. First, if a cool-season grass such as ryegrass was planted along with a warm-season perennial such as Bermudagrass due to time of year, excess ryegrass seed could lead to over-competition in favor of the ryegrass. This might severely limit the establishment of the warm-season grass later on.

The second case would be where seeding the warm season grass at high rates might lead to a bigger stand initially but lead to losses in later dryer, hotter months. It was noted however that this condition would not mean the complete loss of the stand. It would rather result in a self-thinning process where seeds that were larger or better placed in the soil germinate first and therefore establish a competitive advantage relative to the rest of the stand during later periods of stress. So while some plants may be lost, some of the community will likely survive.

There is no single seed rate that will be best for all situations. Rather, the context of site, soil, climate, budget, time frame, and establishment goals must decide the issue. A good example is Bermudagrass. The widely used seeding rate for Bermudagrass in an agricultural application is 8–10 lb/acre. However, turf establishment guidelines typically state that 2 lb/1000 ft^2 (87 lb PLS/acre). Both rates have been used successfully in each application. In transitional zone states such as Indiana and Kansas, up to 44 lb PLS/acre of Bermudagrass has been found to give good stands with rates of 120 lb PLS/acre providing stands capable of withstanding the winters in the Kentucky region.

The seed rate for native grasses will vary as well depending on location and goals. For example, a recommended mix of native grasses for seeding in Maryland includes six species with a total rate of 17–35 lb PLS/acre. Texas Agricultural Extension Service pamphlets call for 6–7 lb PLS/ac (drill-seeded) for grassland restoration.

Research has shown that there is a maximum seed rate beyond which added seed does not result in any significant benefit although no negative effects were noted for high seed rates. A study at Louisiana State University (LSU) showed that first-harvest yields of ryegrass can be increased by planting at higher seed rates but that total yields over time are unchanged. Another study showed that Bermudagrass coverage at 14 days after seeding was not improved by seeding more than 49 kg/ha (44 lb acre) and that for all seeding rates studied, 12 kg/ha (5 lb/acre) to 149 kg/ha (132 lb/acre) produced similar coverage 42 days after seeding.

The difference between these rates and those provided by the NRCS and Texas range specialists is that the grasses used in the studies received all the resources they needed to establish and grow as fast as possible. The significance of this difference is that it shows that the effects of competition between plants for resources can be compensated for by supplementing those resources. Also, since these resources vary with location and with budgets, seeding rates may also vary to compensate for them.

Arriving at a seeding rate tailored to a specific site requires an assessment of soil structure, soil nutrients, slope, rainfall rates, time of seeding, and budget. A high seed rate used in fairly level soils with good nutrient levels in a high-rainfall area could be expected to show faster establishment than would the same rate used on a steep slope of gravely soils in a low-rainfall area.

There is a lack of hard data to firmly support seeding rate recommendations, although some widely accepted standards are considered as baselines. Beyond these baseline estimates it is widely considered best to base the seed rates on a number factors related to the site. These include (this list may not complete):

- soil type,
- soil structure,
- soil depth,
- nutrient availability,
- slope,
- site preparation measures,
- weed control measures,
- rainfall,
- time of seeding,
- seeding method,
- seed species,
- seed physiology,
- budget,
- short-term goals,
- long-term goals, and
- post-seeding management.

The most widely cited baseline or benchmark is 20-40 pure live seeds per square-foot (sf). These rates have been used in numerous studies for comparison of seed establishment between various species of grasses, forbs, and shrubs. The lower end of this range is considered applicable to well-prepared seed beds in sites with no significant limiting factor. The higher end of the rate is considered applicable to sites where some aspect of the site places severe constraints on seedling survivability.

The basic 20-40 PLS/sf rate forms the baseline of the recommendations of the NRCS. These numbers were developed within the area of agricultural applications such as field crops, rangelands, and grazing pastures. Economics is a major factor contributing to these rates. The cost of seeding large areas with seed of just a few dollars per pound of could easily equate to thousands of dollars. Also, the objective of rangeland seeding was not to establish quick vegetation cover but to establish the presence of some desirable species that would increase over a number of years. This same approach is used by grassland and prairie restorationists where the goal is long-term ecological improvement. In each instance, the same limitations of size and budget are usually the major constraints.

It is clear from the literature however that these rates are the minimum for the given circumstance, not the maximum. Sources typically note that seeding rates should be established based on the specific site and adjusted accordingly. The biggest gap in information occurs here. There are no figures provided in the literature reviewed that indicates how much to adjust seeding rates for specific conditions. For example, there is no established adjustment rate for "soil thickness less than…" or "soil slopes exceeding…." or "erosion potential levels of…." In these cases, it is either stated or assumed that the planner should make these allowances based on his or her experience and understanding of the site (or at least using others with those traits). There is no written guide on how much a seeding rate should be adjusted for a specific site condition.

Given this lack of guidance in the literature, the important question is then: how much can a seed rate be increased? Research has found a clear answer for this although its practical application is not so easily discernable. The Law of Constant Yield (Kira et al., 1953) states that there is a maximum carrying capacity of the soil past which the establishment of more plants will not increase the actual yield (biomass). This is well documented in many studies.

Therefore, to determine the optimal seeding rate, the planner needs know the carrying capacity (resources available to the seed). In agricultural applications, soil samples are typically used to provide this information. In most other instances, however, "rules-of-thumb" may be used in assuming some necessary supplement to existing resources.

What are the effects of high seed rates? In the turf industry, seed rates are much higher than in agricultural or restoration/rehabilitation projects. For example, 6 lb/acre of Bermudagrass seed in these situations in common. However, for lawns, playing fields, and golf courses the recommended rate is 44 lb/acre (2 lb/sf) (rates as high as 120 lb/acre have been used in some studies). The difference between these two approaches lies in the amount of resources provided before, during, and after establishment. Turf planners increase the carrying capacity of the soil through extensive enhancement of the resources available to the seed. The goal behind this approach is *speed of establishment*.

Most non-agricultural uses need quick establishment so that the turf can be ready for its intended use as soon as possible. Speed of establishment has other benefits as well. Quicker establishment reduces losses due to erosion and also reduces the severity of weed invasion after seeding. Erosion control is vitally important in roadside applications and is the ultimate goal of vegetation establishment, but there are ways to address erosion (mulches, blankets, tackifiers, etc.) that will not limit seed establishment. Weed invasion, however, may be more critical since the benefits of the fertilizer which are given to the desired seed is also given to the undesired weed.

Competition for resources is the underlying mechanism governing seed rate determination. This competition occurs between the plants of the seeded species as well as between the seeded species and invading weeds. In most roadside conditions, this competition can be very much in the favor of the weed species. This is because most weed invaders of open soils are annuals whose seeds germinate quickly, grow rapidly, and often overshadow slower-growing grass seedlings.

The seed for this invasion is almost always present in the new topsoil placed on the roadside. This “seed bank” may be great or minimal but virtually never completely absent. Also, it is not possible to predict the specific weedy invader that will appear. It could be a desirable grass or it could be giant ragweed. It is not possible to estimate the degree of competition that the new seeds will face. What is known though, is that vegetation will develop on the site to the level of its maximum carrying capacity. How much of that capacity will be grass and how much will be weed can be influenced by the seeding rate.

Studies have shown that high seeding rates reduce weed invasion. Less weed invasion means faster establishment of the seeded species (and better erosion control). The goal of high seeding rates is to reach the maximum carrying capacity sooner so that the soil has less exposure to wind-borne weed seed and there are more of the desired seed competing with weed seed already present in the soil.

At higher rates, seedlings will compete between themselves as well as with weeds. Some self-thinning may occur. However, this thinning itself will not mean the demise of the entire planting. Some seed will be slightly larger, some will land in a better soil position, and some will break dormancy sooner. The result will be a variation in vigor (and size) between the seedlings; some better equipped to survive later stresses such as competition or drought, and some not as well equipped. The same will be true for the weeds present. It becomes a race to see how many of individuals of each group will eventually comprise the greater portion of the maximum carrying capacity.

Awareness of these interactions still does not provide an easy answer to the question of seeding rates. In many ways it complicates the process by forcing consideration of a wider range of variables and potential outcomes. As mentioned earlier, there are many factors that can be considered when designing a seeding program. Ultimately, a decision will have to be made as to which, when, and to what degree each of these factors should be part of the process.

RECOMMENDATIONS

Recommendation #1: Native Seed Mix vs. TxDOT Standard Mix

Based on test results the research team does not recommend the inclusion of an all-native seed mix to TxDOT practice for the following reasons:

- The all-native seed mixes established lower percent vegetation cover, or showed no significant difference during the test period as well as had a slower germination rate in 17 out of 18 test applications than the TxDOT Standard Mixes.

- While there were many individual native seed species which produced well, almost all of these particular seeds species are already included in the current TxDOT Standard seed mix.

Recommendation #2: Increased Seed Rate

Based on the test results the research team does not recommend increasing the TxDOT Standard District Seed Mixes for the following reason: the higher percent vegetation initially produced on the increased seed mix test plots lasted only a short duration. This initial flush of vegetation on the increased seed mix plots actually established a lower overall percent vegetative cover. This was due to the lack of nutrients available in the soil to sustain that high amount of vegetation. Unfortunately, the time constraints of this project do not allow the opportunity to monitor and follow vegetation production and viability.

Recommendation #3: Soil Analysis

One problem which was apparent from the start of this project was the inadequate soils imported to the HSECL for testing. The single most important requirement for soil selection was that it should be typical of what is commonly found and used in each of the representative districts. Soil reports indicated that most of the soils contained inadequate levels of the basic nutrients (N-P-K), pH, and organic content. Current TxDOT Specification Item 160 indicates that topsoil obtained from outside the row must have a pH of 5.5 – 8.5.

Based on these test results the researchers recommend that soils are tested prior to seed planting to ensure proper levels of organic content. Additional organic content may be needed to improve soil structure and promote vegetation establishment. See discussion on Topsoil/Organic Content on page 45 for more information.

The research team has determined that the TxDOT vegetation establishment practices (including seeding) mirror the most widely accepted standards of practice used by agencies, programs, and practitioners throughout the United States. Applied as general rules and fundamental practice, they have been well-suited to meet the vast majority of vegetation establishment needs. Arriving at a seeding rate tailored to a specific site requires an assessment of soil structure, soil nutrients, slope, rainfall rates, time of seeding, and budget. It is common, however, for general rules and fundamentals to fall short when special needs collide with complex, site-specific problems. A site-specific process that could be directly applied when the situation warranted, would provide a greater set of tools and flexibility for TxDOT to meet varying needs. This process would take into account each of the site variables to ensure the most efficient vegetation establishment.

COMPOST-DERIVED FERTILIZER LEACHATE STUDY

Since there are no standard limits for specific nutrients within compost runoff, the research team compared runoff analysis from the compost tests to existing EPA standards for drinking water, livestock water, and irrigation water (Table 3). These standards are set by the EPA to monitor and control the amount of contaminants in our nation's water. The EPA has established standards for runoff from compost manufacturing facilities but not for compost application treatments. While compost runoff is not expected to pass EPA standards for drinking water, or even livestock water, it is reasonable to expect the runoff to pass irrigation water limits as many times storm water is collected and used for that purpose.

Runoff from the two fertilizer applications and the fertilize/compost application all fell within the acceptable limits for irrigation water. The following chart summarizes the data on some essential nutrients and compounds. In all cases, the allowable parts-per-million were below accepted levels for irrigation water. Only Total Dissolved Salts were high in the drinking water category. Based on these results, the higher levels of nitrogen application of the Houactinite and the addition of compost to the topsoil do not pose a problem for runoff water quality.

Table 3. Runoff from Fertilizer Applications.

13-13-13 Fertilizer (100 lb nitrogen/acre)							
Nutrient	**2 hr**	**2.5 hr**	**3.5 hr**	**4 hr**	**Units**	**Drinking water limits**	**Irrigation water limits**
Potassium – K	6	5	4	5	ppm	NE*	NE
Nitrate- N	0.23	0.3	0.24	0.19	ppm	10 ppm	<40 ppm
Phosphorus – P	0.85	0.87	0.85	1.26	ppm	NE	NE
Total dissolved salts	842	814	840	828	ppm	500 ppm	NE
23-0-3 Fertilizer (100 lb nitrogen/acre)							
Nutrient	**2 hr**	**2.5 hr**	**3.5 hr**	**4 hr**	**Units**	**Drinking water limits**	**Irrigation water limits**
Potassium – K	28	26	21	21	ppm	NE	NE
Nitrate- N	0.88	0.63	0.68	0.59	ppm	10 ppm	<40 ppm
Phosphorus – p	0.96	0.91	0.83	0.82	ppm	NE	NE
Total dissolved salts	974	948	896	893	ppm	500 ppm	NE
6-3-0 Houactinite Compost (240 lb nitrogen/acre)							
Nutrient	**2 hr**	**2.5 hr**	**3.5 hr**	**4 hr**	**Units**	**Drinking water limits**	**Irrigation water limits**
Potassium – K	181	194	126	116	ppm	NE	NE
Nitrate- N	0.09	0.09	0.06	0.03	ppm	10 ppm	<40 ppm
Phosphorus – p	6.37	6.19	5	4.07	ppm	NE	NE
Total dissolved salts	2315	2157	1591	1571	ppm	500 ppm	NE
* NE = Not Established							

It was thought that the higher nitrogen rate of the Houactinite would also be reflected in the runoff totals. It is surmised that the nitrogen adhered to the high amounts of organic material found in the compost. Organic aggregates contain more nitrogen-fixing bacteria and tend to hold nitrogen molecules. The nutrient-holding capability of organic content is well known and in this case may be responsible for the lower rates of nitrogen found in the runoff. Since the tests were not structured to answer this question, more study would be needed to verify this hypothesis.

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Appendix A
Soil Analysis

Abilene Clay

PARTICLE SIZE ANALYSIS

Product	Abilene Clay
Date	6/23/2004
Clay/Sand	Clay
Round	N/A
Slope	N/A
Technician	Hao (test) Derrold (data entry)

TOTAL WEIGHT OF DRY SAMPLE 300.0 **g**

SIEVE SIZE	WT. RETAINED	%AGE PASSING
1in.	0	100
3/4in.	0	100
1/4in.	4.66	98.44666667
No.4(4.75mm)	3.4	97.31333333
No.10(2mm)	7	94.98
No.40(425microm)	41.17	81.25666667
No.100	54.24	63.17666667
No.200(75microm)	55.91	44.54
Passing No.200	133.62	N/A

Hydrometer Analysis

Time (minutes)	Hydrometer reading	Corr. Hyd. Reading	Eff. L	Dia=K*Sqrt(L/T)	N%	Corr. N%
1	44	42	9.1	0.039668561	84	37.4136
2	41	39	9.6	0.028810207	78	34.7412
5	38	36	10.1	0.018689662	72	32.0688
15	33	31	10.9	0.011209684	62	27.6148
30	29	27	11.5	0.00814168	54	24.0516
60	26	24	12	0.005880859	48	21.3792
250	19	17	13.2	0.00302164	34	15.1436
1440	13	11	14.2	0.001305935	22	9.7988

Cm= 1 **Cd=** 3 **Temperature=** 23.2 c

Abilene Sand

PARTICLE SIZE ANALYSIS

Product	Abilene Sand
Date	6/15/2004
Clay/Sand	Sand
Round	N/A
Slope	N/A
Technician	Hao (test) Derrold (data entry)

TOTAL WEIGHT OF DRY SAMPLE 500.0 **g**

SIEVE SIZE	WT. RETAINED	%AGE PASSING
1in.	0	100
3/4in.	0	100
1/4in.	2.08	99.584
No.4(4.75mm)	0.68	99.448
No.10(2mm)	0.94	99.26
No.40(425microm)	21.85	94.89
No.100	325.38	29.814
No.200(75microm)	104.81	8.852
Passing No.200	40.78	N/A

Austin Clay

PARTICLE SIZE ANALYSIS

Product	Austin Clay
Date	6/23/2004
Clay/Sand	Clay
Round	N/A
Slope	N/A
Technician	Hao (test) Derrold (data entry)

TOTAL WEIGHT OF DRY SAMPLE 300.0 **g**

SIEVE SIZE	WT. RETAINED	%AGE PASSING
1in.	0	100
3/4in.	0	100
1/4in.	2.82	99.06
No.4(4.75mm)	0.75	98.81
No. 10(2mm)	4.24	97.39666667
No.40(425microm)	27.75	88.14666667
No.100	57.38	69.02
No.200(75microm)	103.19	34.62333333
Passing No.200	103.87	N/A

Hydrometer Analysis

Time (minutes)	Hydrometer reading	Corr. Hyd. Reading	Eff. L	Dia=K*Sqrt(L/T)	N%	Corr. N%
1	25	23	12.2	0.045930975	46	15.9252
2	21	19	12.9	0.033396858	38	13.1556
5	19	17	13.2	0.021366221	34	11.7708
15	18	16	13.3	0.012382432	32	11.0784
30	17	15	13.5	0.008821288	30	10.386
60	16	14	13.7	0.006283627	28	9.6936
250	15	13	13.8	0.00308955	26	9.0012
1440	12	10	14.3	0.001310526	20	6.924

Cm= 1 **Cd=** 3 **Temperature=** 23.2 c

Austin Sand

PARTICLE SIZE ANALYSIS

Product	Austin Sand
Date	6/14/2004
Clay/Sand	Sand
Round	N/A
Slope	N/A
Technician	Hao (test) Derrold (data entry)

TOTAL WEIGHT OF DRY SAMPLE 500.0 **g**

SIEVE SIZE	WT. RETAINED	%AGE PASSING
1in.	0	100
3/4in.	0	100
1/4in.	6.44	98.712
No.4(4.75mm)	0	98.712
No. 10(2mm)	19.07	94.898
No.40(425microm)	109.7	72.958
No.100	283.62	16.234
No.200(75microm)	48.01	6.632
Passing No.200	32.78	N/A

Corpus Christi Clay

PARTICLE SIZE ANALYSIS

Product	Corpus Christi Clay
Date	6/23/2004
Clay/Sand	Clay
Round	N/A
Slope	N/A
Technician	Hao (test) Derrold (data entry)

TOTAL WEIGHT OF DRY SAMPLE 300.0 **g**

SIEVE SIZE	WT. RETAINED	%AGE PASSING
1in.	0	100
3/4in.	0	100
1/4in.	13.45	95.51666667
No.4(4.75mm)	3.56	94.33
No. 10(2mm)	5.43	92.52
No.40(425microm)	4.73	90.94333333
No.100	12.41	86.80666667
No.200(75microm)	46.28	71.38
Passing No.200	214.14	N/A

Hydrometer Analysis

Time (minutes)	Hydrometer reading	Corr. Hyd. Reading	Eff. L	Dia=K*Sqrt(L/T)	N%	Corr. N%
1	46	44	8.8	0.039305852	88	62.8144
2	44	42	9.1	0.028263216	84	59.9592
5	41	39	9.9	0.018644403	78	55.6764
15	38	36	10.1	0.010872538	72	51.3936
30	36	34	10.4	0.007801389	68	48.5384
60	34	32	10.7	0.005595413	64	45.6832
250	28	26	11.7	0.002866413	52	37.1176
1440	24	22	12.4	0.001229641	44	31.4072

Cm= 1 **Cd=** 3 **Temperature=** 22.6 c

Corpus Christi Sand

PARTICLE SIZE ANALYSIS

Product	Corpus Christi Sand
Date	6/15/2004
Clay/Sand	Sand
Round	N/A
Slope	N/A
Technician	Hao (test) Derrold (data entry)

TOTAL WEIGHT OF DRY SAMPLE 500.0 **g**

SIEVE SIZE	WT. RETAINED	%AGE PASSING
1in.	0	100
3/4in.	0	100
1/4in.	0	100
No.4(4.75mm)	0	100
No. 10(2mm)	0.34	99.932
No.40(425microm)	71.56	85.62
No.100	391.01	7.418
No.200(75microm)	25.81	2.256
Passing No.200	10.99	N/A

Houston Clay

PARTICLE SIZE ANALYSIS

Product	Houston Clay
Date	10/25/2005
Clay/Sand	Clay
Round	
Slope	
Technician	Travis Peiffer

TOTAL WEIGHT OF DRY SAMPLE 300.0 **g**

SIEVE SIZE	WT. RETAINED	%AGE PASSING
1/4in.	12.27	95.91
No.4(4.75mm)	9.07	92.88666667
No. 10(2mm)	14.5	88.05333333
No.40(425microm)	11.07	84.36333333
No.100	31.82	73.75666667
No.200(75microm)	45.21	58.68666667
Passing No.200	176.06	N/A

Hydrometer Analysis

Time (minutes)	Hydrometer reading	Corr. Hyd. Reading	Eff. L	Dia=K*Sqrt(L/T)	N%	Corr. N%
1	27	25	12.2	0.045284798	50	22.27
2	25	23	12.5	0.0324125	46	20.4884
5	23	21	12.9	0.020824874	42	18.7068
15	18	16	13.7	0.012390453	32	14.2528
30	17	15	13.8	0.008793291	30	13.362
60	15	13	14.2	0.006307265	26	11.5804
240	13	11	14.5	0.003186771	22	9.7988
1440	10	8	15	0.001323235	16	7.1264

Cm= 1 **Cd=** 3 **Temperature=** 24.3° c

Houston Sand

PARTICLE SIZE ANALYSIS

Product	Houston Sand
Date	10/25/2005
Clay/Sand	Sand
Round	
Slope	
Technician	T. Peiffer

TOTAL WEIGHT OF DRY SAMPLE 500 **g**

SIEVE SIZE	WT. RETAINED	%AGE PASSING
1/4in.	57.15	88.57
No.4(4.75mm)	27.04	83.162
No. 10(2mm)	80.52	67.058
No.40(425microm)	103.45	46.368
No.100	132.73	19.822
No.200(75microm)	60.38	7.746
Passing No.200	38.1	N/A

Lufkin Clay

PARTICLE SIZE ANALYSIS

Product	Lufkin Clay
Date	6/25/2004
Clay/Sand	Clay
Round	N/A
Slope	N/A
Technician	Hao (test) Derrold (data entry)

TOTAL WEIGHT OF DRY SAMPLE 300.0 **g**

SIEVE SIZE	WT. RETAINED	%AGE PASSING
1in.	0	100
3/4in.	0	100
1/4in.	18.81	93.73
No.4(4.75mm)	8.2	90.99666667
No. 10(2mm)	12.7	86.76333333
No.40(425microm)	12.25	82.68
No.100	33.06	71.66
No.200(75microm)	85.84	43.04666667
Passing No.200	129.14	N/A

Hydrometer Analysis

Time (minutes)	Hydrometer reading	Corr. Hyd. Reading	Eff. L	Dia=K*Sqrt(L/T)	N%	Corr. N%
1	34	32	10.7	0.043570858	64	28.032
2	31	29	11.2	0.031520873	58	25.404
5	27	25	11.9	0.020549095	50	21.9
15	23	21	12.5	0.012159441	42	18.396
30	20	18	13	0.008768297	36	15.768
60	18	16	13.3	0.006271254	32	14.016
250	14	12	14	0.003152087	24	10.512
1440	12	10	14.3	0.001327367	20	8.76

Cm= 1 **Cd=** 3 **Temperature=** 22 c

Lufkin Sand

PARTICLE SIZE ANALYSIS

Product	Lufkin Sand
Date	6/25/2004
Clay/Sand	Sand
Round	N/A
Slope	N/A
Technician	Hao (test) Derrold (data entry)

TOTAL WEIGHT OF DRY SAMPLE 500.0 **g**

SIEVE SIZE	WT. RETAINED	%AGE PASSING
1in.	0	100
3/4in.	0	100
1/4in.	6.36	98.728
No.4(4.75mm)	4.85	97.758
No. 10(2mm)	16.65	94.428
No.40(425microm)	19.69	90.49
No.100	398.42	10.806
No.200(75microm)	42.7	2.266
Passing No.200	13.24	N/A

San Angelo Clay

PARTICLE SIZE ANALYSIS

Product	San Angelo Clay
Date	11/3/2005
Clay/Sand	Clay
Round	
Slope	
Technician	Travis Peiffer

TOTAL WEIGHT OF DRY SAMPLE 300.0 **g**

SIEVE SIZE	WT. RETAINED	%AGE PASSING
1/4in.	56.3	81.23333333
No.4(4.75mm)	26.4	72.43333333
No. 10(2mm)	75.31	47.33
No.40(425microm)	35.48	35.50333333
No.100	19.62	28.96333333
No.200(75microm)	3.05	27.94666667
Passing No.200	83.83	N/A

Hydrometer Analysis

Time (minutes)	Hydrometer reading	Corr. Hyd. Reading	Eff. L	Dia=K*Sqrt(L/T)	N%	Corr. N%
1	36	34	10.7	0.042409623	68	30.2872
2	32	30	11.4	0.030953513	60	26.724
5	27	25	12.2	0.020251977	50	22.27
15	20	18	13.3	0.01220823	36	16.0344
30	11	9	14.8	0.009106317	18	8.0172
60	11	9	14.8	0.006439138	18	8.0172
240	9	7	15.2	0.003262787	14	6.2356
1440	8	6	15.3	0.001336402	12	5.3448

Cm= 1 **Cd=** 3 **Temperature=** 24° c

Appendix B
Project Seed Rates

Abilene Texas Seed Rates

Native Seed Rate

Species	PLS Rate (lb/acre)
Alkali Sacaton	0.2
Blue Grama (Hachita)	0.3
Buffalograss (Texoka)	1.6
Sideoats Grama (Niner)	0.9
Sand Dropseed	0.2
Galleta (Viva)	0.4
Indian Ricegrass (Paloma)	0.4
Little Bluestem	0.68
Sand Bluestem	1.2
Spike Muhly (El Vado)	0.2
Illinois Bundleflower	13.6
Partridge Pea	13.4
Engelmann Daisy	15

Standard Seed Rate

Clay Soils

Species	PLS Rate (lb/acre)
Green Sprangletop	0.3
Sideoats Grama (Haskell)	2.7
Blue Grama (Hachita)	0.9
Galleta (Viva)	1.6
Buffalo Grass (Texoka)	1.6
Little Bluestem	1.7
Illinois Bundleflower	1

Sandy Soils

Green Sprangletop	0.3
Sand Bluestem	3
Weeping Love gr. (Ermelo)	1.2
Sand Dropseed	0.5
Purple Prairieclover	0.5

Austin Texas Seed Rates

Native Seed Rate

Species	PLS Rate (lb/acre)
Blue Grama (Hachita)	0.375
Little Bluestem	0.85
Sideoats Grama (El Reno)	1.125
Sand Lovegrass	0.375
Buffalograss (Texoka)	2
Green Sprangletop	0.425
Sand Dropseed	0.25
Purple Three-Awn	1
Illinois Bundleflower	13.6
Partridge Pea	13.4
Englemann Daisy	15

Standard Seed Rate

Clay Soils

Species	PLS Rate (lb/acre)
Green Sprangletop	0.3
Common Bermuda	0.9
Sideoats Grama (Haskell)	2.7
Little Bluestem	1
Blue Grama (Hachita)	0.9
Illinois Bundleflower	1

Sandy Soils

Green Sprangletop	0.3
Common Bermuda	2.4
Weeping Love gr. (Ermelo)	0.8
Sand Lovegrass	0.8
Partridge Pea	1

Corpus Christi TX Seed Rates

Native Seed Rate

Species	PLS Rate (lb/acre)
Green Sprangletop	0.57
Sideoats Grama (El Reno)	1.5
Plains Bristlegrass	1
Buffalograss (Texoka)	2.67
Spike Muhly (El Vado)	0.33
Sand Dropseed	0.33
Illinois Bundleflower	13.6
Partridge Pea	13.4
Englemann Daisy	15

Standard Seed Rate

Clay Soils

Species	PLS Rate (lb/acre)
Green Sprangletop	0.3
Sideoats Grama (Haskell)	2.7
Common Bermuda	1.8
Buffalograss (Texoka)	1.6
Plains Bristlegrass	1.2
Illinois Bundleflower	1

Sandy Soils

Green Sprangletop	0.3
Common Bermuda	1.8
Common Buffelgrass	0.4
Sand Lovegrass	0.6
Purple Prairieclover	0.5

Lufkin Texas Seed Rates

Native Seed Rate

Species	PLS Rate (lb/acre)
Sideoats Grama (El Reno)	1.5
Green Sprangletop	0.57
Sand Lovegrass	0.5
Purple Three Awn	1.33
Native Coastal Prairie Mix	2.33
Bushy Bluestem	1.13
Illinois Bundleflower	13.6
Partridge Pea	13.4
Englemann Daisy	15

Standard Seed Rate

Clay Soils

Species	PLS Rate (lb/acre)
Green Sprangletop	0.3
Common Bermuda	1.8
Bahiagrass (Pensacola)	9
Sideoats Grama (Haskell)	2.7
Illinois Bundleflower	1

Sandy Soils

Green Sprangletop	0.3
Common Bermuda	2.1
Bahiagrass (Pensacola)	9
Sand Lovegrass	0.5
Lanceleaf Coreopsis	1

Houston TX Seed Rates

Increased District Rate I

Clay and Sandy Soils

Species	PLS Rate (lb/acre)
Green Sprangletop	4
Sideoats Grama (Haskell)	3.2
Hulled Bermudagrass	26
Little Bluestem (Native)	1.4
Foxtail Millet	34

Standard TX-DOT Rate – Houston Dist

Clay Soils

Species	PLS Rate (lb/acre)
Green Sprangletop	0.3
Common Bermuda	2.4
Sideoats Grama (Haskell)	4.5

Sandy Soils

Green Sprangletop	0.3
Common Bermuda	5.4

San Angelo TX Seed Rates

Increased District Rate II

Clay and Sandy Soils

Species	PLS Rate (lb/acre)
Buffalograss (Texoka)	110
Common Bermuda	110
Tall Fescue	110

Standard Tx-DOT Rate - San Angelo

Clay Soils

Species	PLS Rate (lb/acre)
Green Sprangletop	0.3
Sideoats Grama (Haskell)	7.2
Buffalograss (Texoka)	1.6

Sandy Soils

Green Sprangletop	0.3
Sideoats Grama (Haskell)	3.2
Sand Dropseed	0.3
Blue Grama (Hachita)	0.9
Buffalograss (Texoka)	1.6

Lufkin TX Cool Season Seed Rates

TX-DOT Cool Season Rate

Species	PLS Rate (lb/acre)
Tall Fescue	4.5
Wheat	34
Oats	24

Native Cool Season Rate

Species	PLS Rate (lb/acre)
Orchardgrass	3.33
Bottlebrush Squirreltail	2
Texas Wintergrass	15

Appendix C
Plant ID Analysis

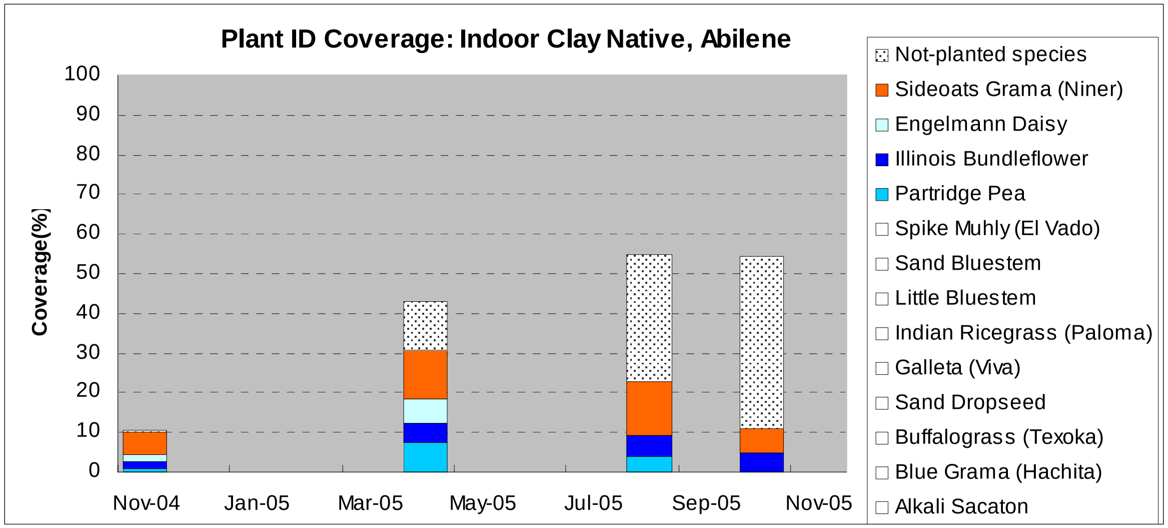
Abilene Region

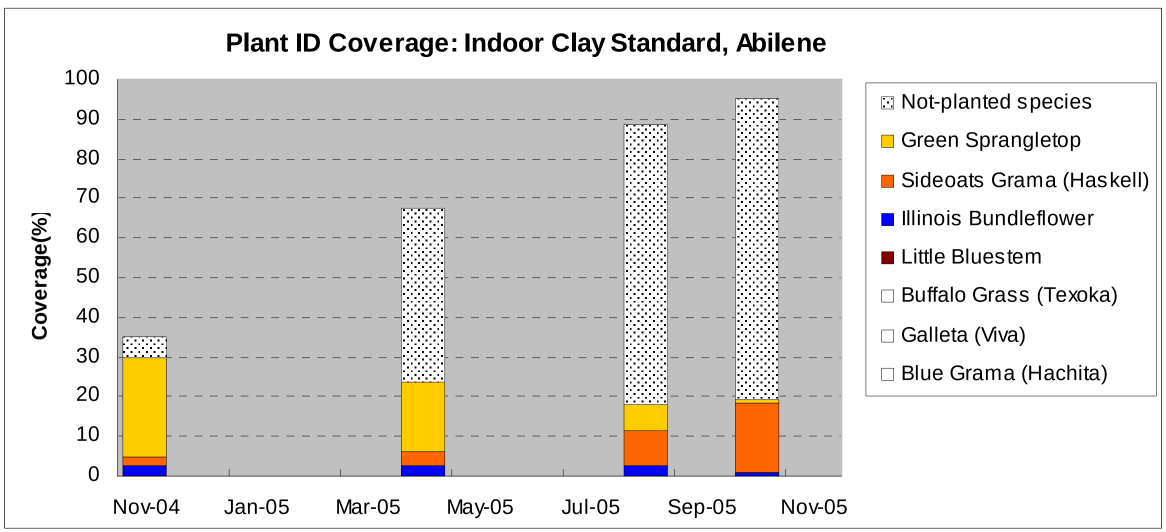
Indoor Clay

Native	11/12/04	4/20/05	8/1/05	10/28/05
V-cap	10.65	43.18	54.68	54.50
Alkali Sacaton	0.00	0.00	0.00	0.00
Blue Grama (Hachita)	0.00	0.00	0.00	0.00
Buffalograss (Texoka)	0.00	0.00	0.00	0.00
Sand Dropseed	0.00	0.00	0.00	0.00
Galleta (Viva)	0.00	0.00	0.00	0.00
Indian Ricegrass (Paloma)	0.00	0.00	0.00	0.00
Little Bluestem	0.00	0.00	0.00	0.00
Sand Bluestem	0.00	0.00	0.00	0.00
Spike Muhly (El Vado)	0.00	0.00	0.00	0.00
Partridge Pea	1.00	7.25	4.00	0.00
Illinois Bundleflower	1.50	5.00	5.00	5.00
Engelmann Daisy	2.00	6.00	0.00	0.00
Sideoats Grama (Niner)	5.50	12.50	14.00	6.00
Not-planted species	0.65	12.43	31.68	43.50

Standard	11/12/04	4/20/05	8/1/05	10/28/05
V-cap	35.10	67.72	88.75	95.26
Blue Grama (Hachita)	0.00	0.00	0.00	0.00
Galleta (Viva)	0.00	0.00	0.00	0.00
Buffalo Grass (Texoka)	0.00	0.00	0.00	0.00
Little Bluestem	0.00	0.00	0.00	0.00
Illinois Bundleflower	2.50	2.50	2.50	0.75
Sideoats Grama (Haskell)	2.50	3.50	9.00	17.50
Green Sprangletop	25.00	17.50	6.50	1.00
Not-planted species	5.10	44.22	70.75	76.01

* All species are Native


Plant ID Coverage: Indoor Clay Native, Abilene
Coverage(%)
100
90
80
70
60
50
40
30
20
10
0
Nov-04
Jan-05
Mar-05
May-05
Jul-05
Sep-05
Nov-05
Not-planted species
Sideoats Grama (Niner)
Engelmann Daisy
Illinois Bundleflower
Partridge Pea
Spike Muhly (El Vado)
Sand Bluestem
Little Bluestem
Indian Ricegrass (Paloma)
Galleta (Viva)
Sand Dropseed
Buffalograss (Texoka)
Blue Grama (Hachita)
Alkali Sacaton


Plant ID Coverage: Indoor Clay Standard, Abilene
Coverage(%)
100
90
80
70
60
50
40
30
20
10
0
Nov-04
Jan-05
Mar-05
May-05
Jul-05
Sep-05
Nov-05
Not-planted species
Green Sprangletop
Sideoats Grama (Haskell)
Illinois Bundleflower
Little Bluestem
Buffalo Grass (Texoka)
Galleta (Viva)
Blue Grama (Hachita)

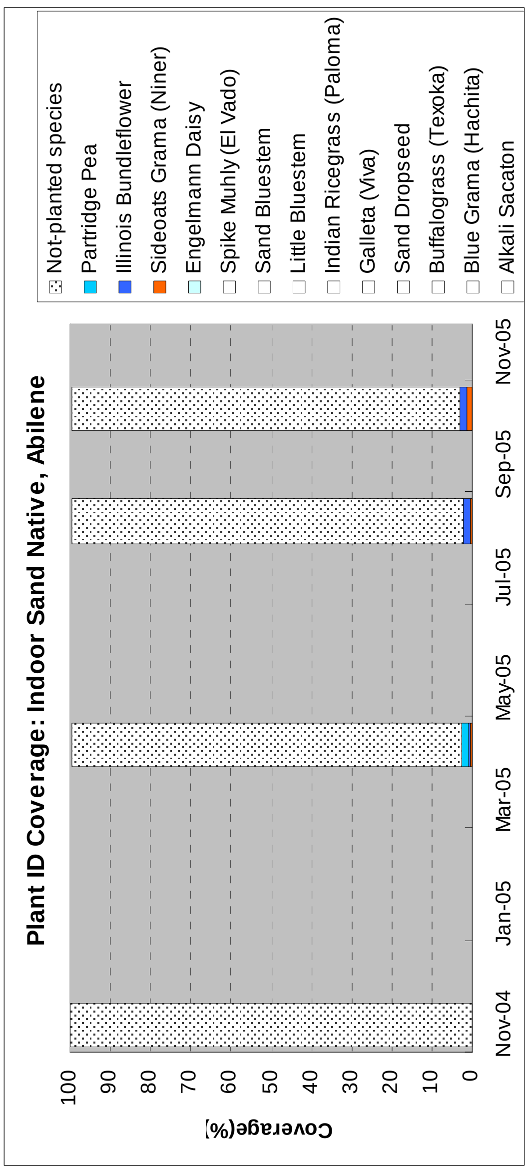
Abilene Region

Indoor Sand

Native	11/12/04	4/20/05	8/1/05	10/28/05
V-cap	100.00	99.77	99.63	99.50
Alkali Sacaton	0.00	0.00	0.00	0.00
Blue Grama (Hachita)	0.00	0.00	0.00	0.00
Buffalograss (Texoka)	0.00	0.00	0.00	0.00
Sand Dropseed	0.00	0.00	0.00	0.00
Galleta (Viva)	0.00	0.00	0.00	0.00
Indian Ricegrass (Paloma)	0.00	0.00	0.00	0.00
Little Bluestem	0.00	0.00	0.00	0.00
Sand Bluestem	0.00	0.00	0.00	0.00
Spike Muhly (El Vado)	0.00	0.00	0.00	0.00
Engelmann Daisy	0.00	0.00	0.00	0.00
Sideoats Grama (Niner)	0.00	0.50	0.50	1.50
Illinois Bundleflower	0.00	0.50	1.50	1.50
Partridge Pea	0.00	1.50	0.00	0.00
Not-planted species	100.00	97.27	97.63	96.50

Standard	11/12/04	4/20/05	8/1/05	10/28/05
V-cap	100.00	99.65	99.43	99.24
Sand Bluestem	0.00	0.00	0.00	0.00
Purple Prairieclover	0.00	0.00	0.00	0.00
Weeping Love gr. (Ermelo)	0.00	0.50	2.00	4.00
Sand Dropseed	10.00	10.00	11.00	11.00
Green Sprangletop	37.50	35.00	5.00	2.00
Not-planted species	52.50	54.15	81.43	82.24

* All species are Native


Plant ID Coverage: Indoor Sand Native, Abilene
Coverage(%)
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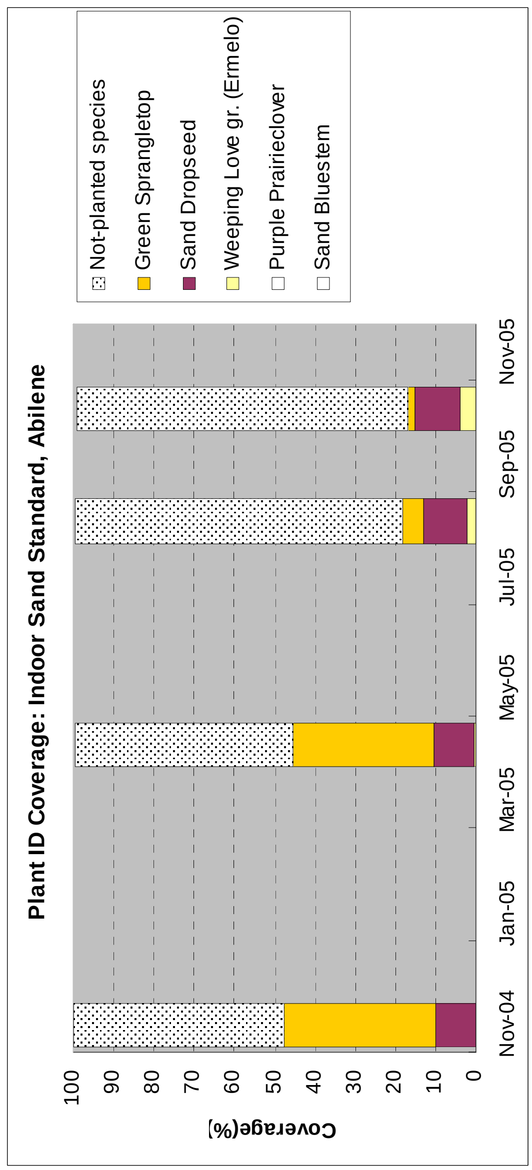
70
60
50
40
30
20
10
0
Nov-04
Jan-05
Mar-05
May-05
Jul-05
Sep-05
Nov-05
Not-planted species
Partridge Pea
Illinois Bundleflower
Sideoats Grama (Niner)
Engelmann Daisy
Spike Muhly (El Vado)
Sand Bluestem
Little Bluestem
Indian Ricegrass (Paloma)
Galleta (Viva)
Sand Dropseed
Buffalograss (Texoka)
Blue Grama (Hachita)
Alkali Sacaton


Plant ID Coverage: Indoor Sand Standard, Abilene
Coverage(%)
100
90
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70
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20
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0
Nov-04
Jan-05
Mar-05
May-05
Jul-05
Sep-05
Nov-05
Not-planted species
Green Sprangletop
Sand Dropseed
Weeping Love gr. (Ermelo)
Purple Prairieclover
Sand Bluestem

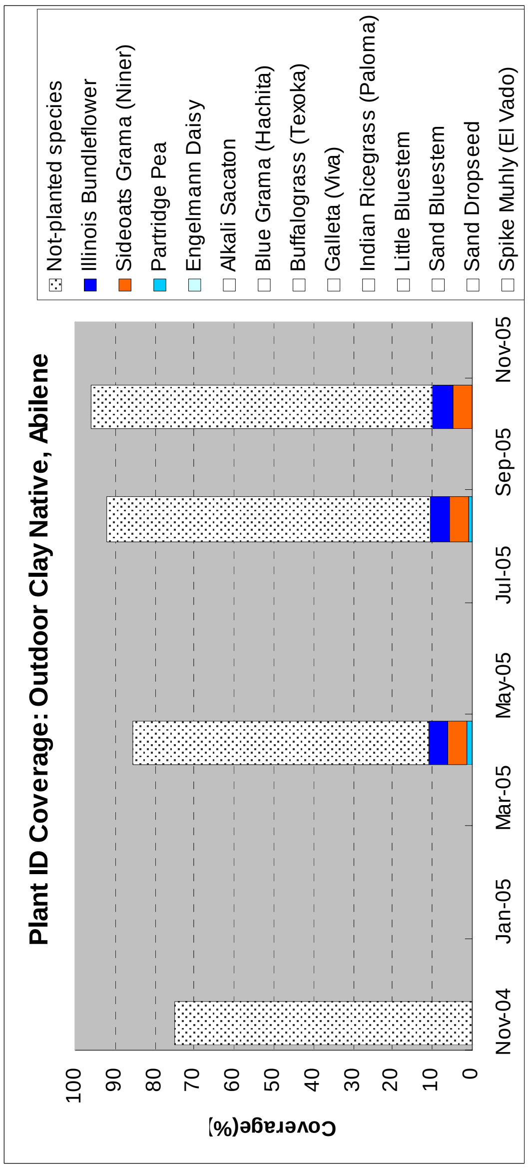
Abilene Region

Outdoor Clay

Native	11/12/04	4/20/05	8/1/05	10/28/05
V-cap	74.89	85.45	92.29	96.27
Spike Muhly (El Vado)	0.00	0.00	0.00	0.00
Sand Dropseed	0.00	0.00	0.00	0.00
Sand Bluestem	0.00	0.00	0.00	0.00
Little Bluestem	0.00	0.00	0.00	0.00
Indian Ricegrass (Paloma)	0.00	0.00	0.00	0.00
Galleta (Viva)	0.00	0.00	0.00	0.00
Buffalograss (Texoka)	0.00	0.00	0.00	0.00
Blue Grama (Hachita)	0.00	0.00	0.00	0.00
Alkali Sacaton	0.00	0.00	0.00	0.00
Engelmann Daisy	0.00	0.17	0.00	0.00
Partridge Pea	0.00	1.00	0.67	0.00
Sideoats Grama (Niner)	0.00	5.00	5.00	5.00
Illinois Bundleflower	0.00	5.00	5.00	5.00
Not-planted species	74.89	74.28	81.62	86.27

Standard	11/12/04	4/20/05	8/1/05	10/28/05
V-cap	95.04	92.30	90.52	89.00
Blue Grama (Hachita)	0.00	0.00	0.00	0.00
Buffalo Grass (Texoka)	0.00	0.00	0.00	0.00
Little Bluestem	0.00	0.00	0.00	0.00
Illinois Bundleflower	0.00	2.00	3.33	0.67
Galleta (Viva)	0.67	0.00	0.00	0.00
Sideoats Grama (Haskell)	13.33	21.83	29.00	43.33
Green Sprangletop	31.67	7.92	2.67	1.67
Not-planted species	49.37	60.55	55.52	43.33

* All species are Native


Plant ID Coverage: Outdoor Clay Native, Abilene
Coverage(%)
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60
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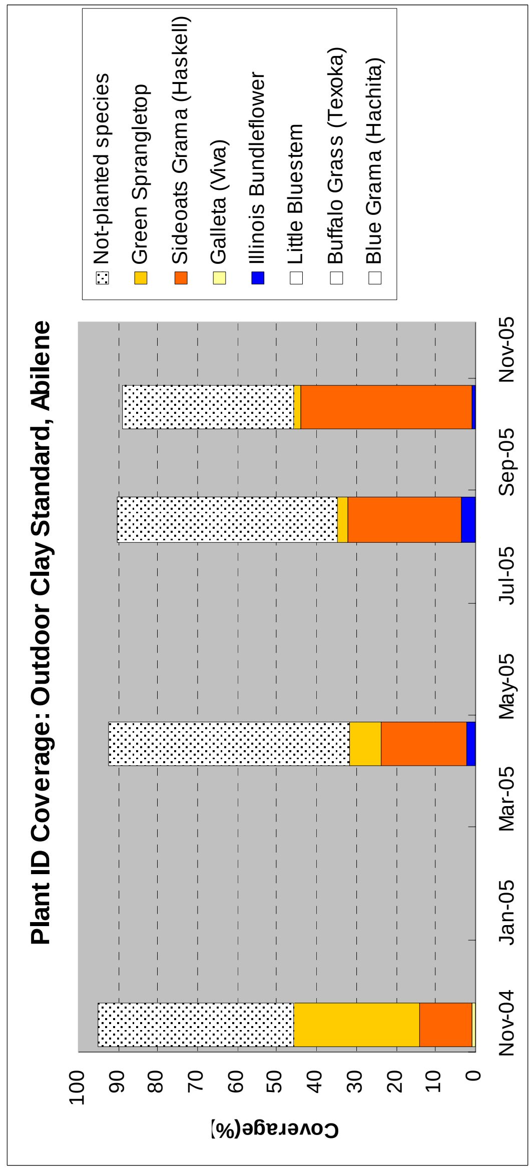
40
30
20
10
0
Nov-04
Jan-05
Mar-05
May-05
Jul-05
Sep-05
Nov-05
Not-planted species
Illinois Bundleflower
Sideoats Grama (Niner)
Partridge Pea
Engelmann Daisy
Alkali Sacaton
Blue Grama (Hachita)
Buffalograss (Texoka)
Galleta (Viva)
Indian Ricegrass (Paloma)
Little Bluestem
Sand Bluestem
Sand Dropseed
Spike Muhly (El Vado)


Plant ID Coverage: Outdoor Clay Standard, Abilene
Coverage(%)
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70
60
50
40
30
20
10
0
Nov-04
Jan-05
Mar-05
May-05
Jul-05
Sep-05
Nov-05
Not-planted species
Green Sprangletop
Sideoats Grama (Haskell)
Galleta (Viva)
Illinois Bundleflower
Little Bluestem
Buffalo Grass (Texoka)
Blue Grama (Hachita)

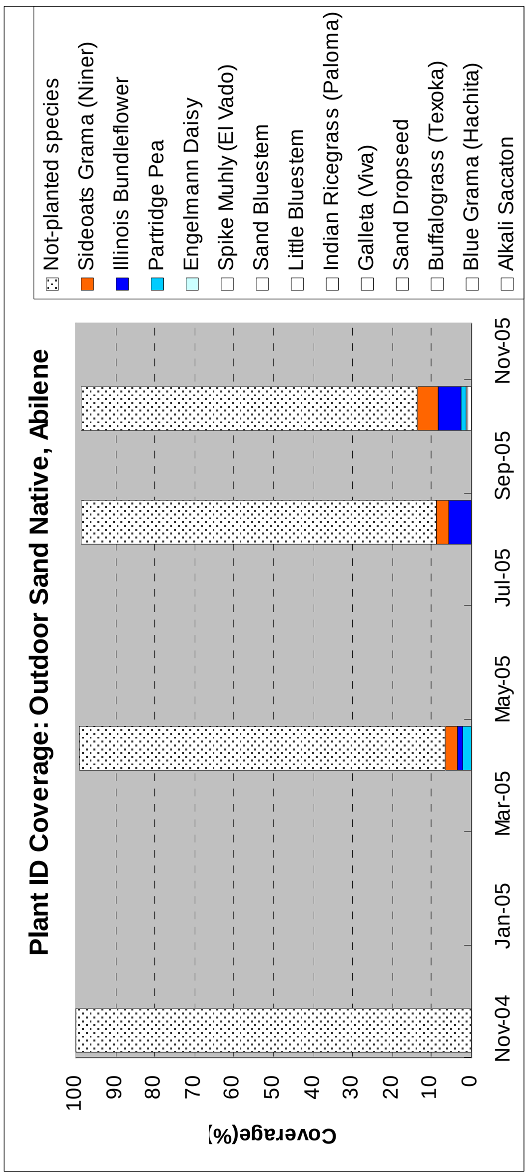
Abilene Region

Outdoor Sand

Native	11/12/04	4/20/05	8/1/05	10/28/05
V-cap	100.00	99.33	98.89	98.52
Alkali Sacaton	0.00	0.00	0.00	0.00
Blue Grama (Hachita)	0.00	0.00	0.00	0.83
Buffalograss (Texoka)	0.00	0.00	0.00	0.00
Sand Dropseed	0.00	0.00	0.00	0.00
Galleta (Viva)	0.00	0.00	0.00	0.00
Indian Ricegrass (Paloma)	0.00	0.00	0.00	0.00
Little Bluestem	0.00	0.00	0.00	0.33
Sand Bluestem	0.00	0.00	0.00	0.00
Spike Muhly (El Vado)	0.00	0.00	0.00	0.00
Engelmann Daisy	0.00	0.00	0.00	0.00
Partridge Pea	0.00	2.33	0.00	1.67
Illinois Bundleflower	0.00	1.33	5.67	5.67
Sideoats Grama (Niner)	0.00	3.00	3.00	5.00
Not-planted species	100.00	92.66	90.22	85.02

Standard	11/12/04	4/20/05	8/1/05	10/28/05
V-cap	100.00	98.66	97.78	97.04
Sand Bluestem	0.00	0.00	0.00	0.00
Purple Prairieclover	0.00	0.00	0.00	0.00
Weeping Love gr. (Ermelo)	0.00	1.33	1.67	6.00
Sand Dropseed	0.00	1.67	2.67	2.67
Green Sprangletop	15.00	14.00	5.00	3.00
Not-planted species	85.00	81.66	88.45	85.37

* All species are Native


Plant ID Coverage: Outdoor Sand Native, Abilene
Coverage(%)
100
90
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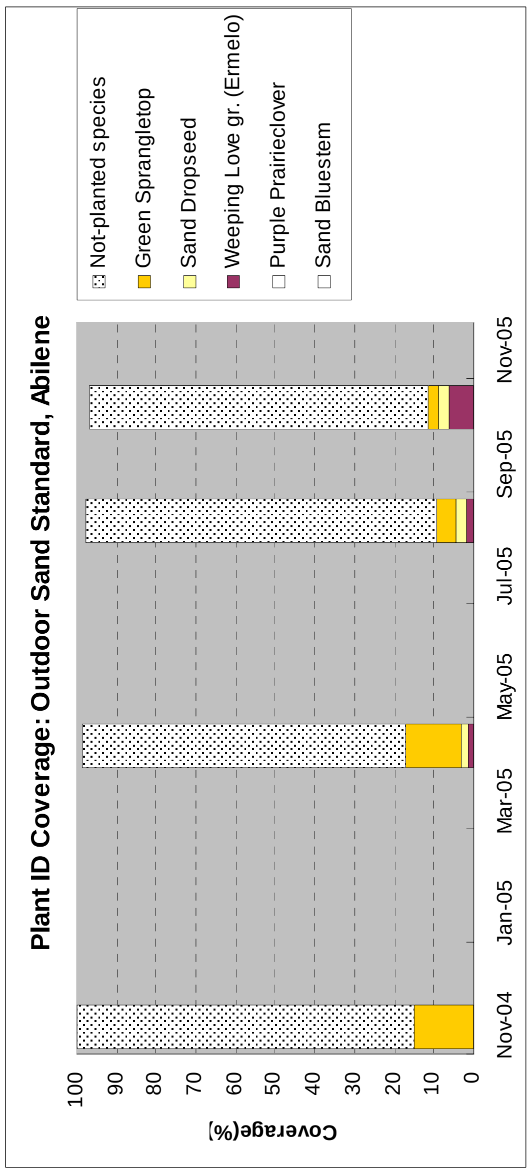
20
10
0
Nov-04
Jan-05
Mar-05
May-05
Jul-05
Sep-05
Nov-05
Not-planted species
Sideoats Grama (Niner)
Illinois Bundleflower
Partridge Pea
Engelmann Daisy
Spike Muhly (El Vado)
Sand Bluestem
Little Bluestem
Indian Ricegrass (Paloma)
Galleta (Viva)
Sand Dropseed
Buffalograss (Texoka)
Blue Grama (Hachita)
Alkali Sacaton


Plant ID Coverage: Outdoor Sand Standard, Abilene
Coverage(%)
100
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70
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20
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0
Nov-04
Jan-05
Mar-05
May-05
Jul-05
Sep-05
Nov-05
Not-planted species
Green Sprangletop
Sand Dropseed
Weeping Love gr. (Ermelo)
Purple Prairieclover
Sand Bluestem

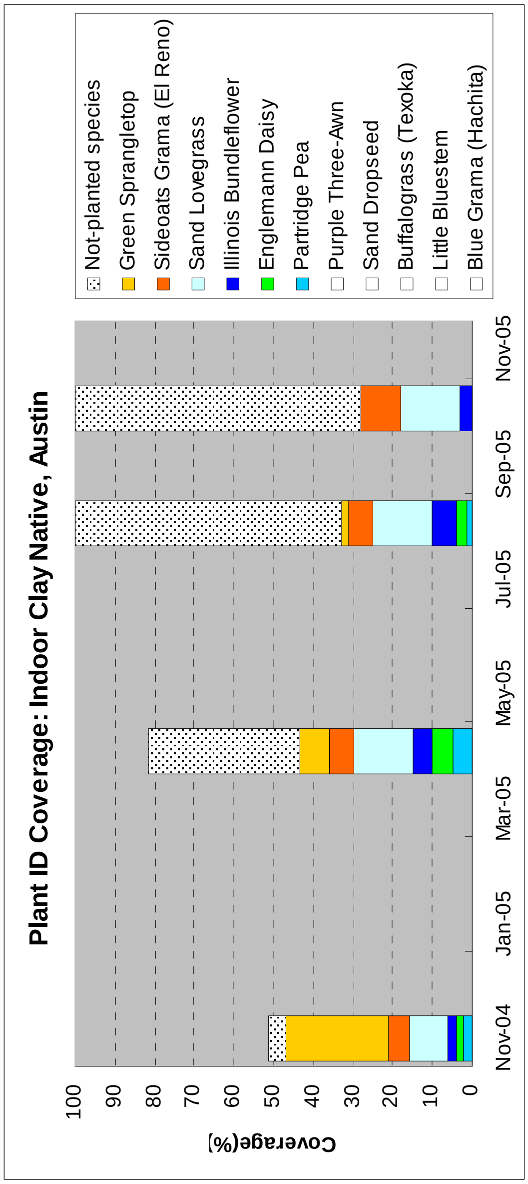
Austin Region

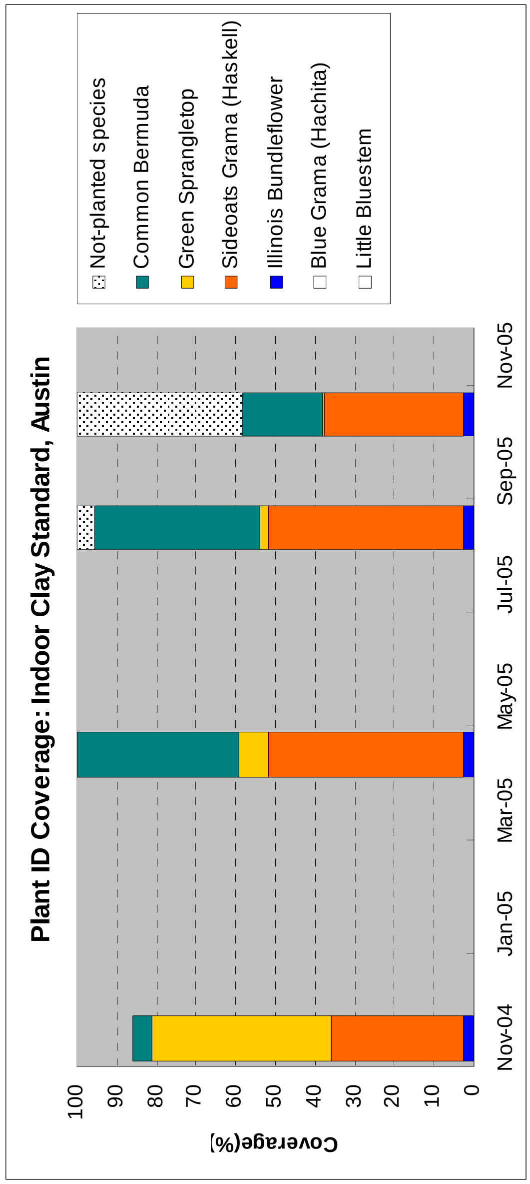
Indoor Clay

Native	11/12/04	4/20/05	8/1/05	10/28/05
V-cap	51.13	81.66	100.00	100.00
Blue Grama (Hachita)	0.00	0.00	0.00	0.00
Little Bluestem	0.00	0.00	0.00	0.00
Buffalograss (Texoka)	0.00	0.00	0.00	0.00
Sand Dropseed	0.00	0.00	0.00	0.00
Purple Three-Awn	0.00	0.00	0.00	0.00
Partridge Pea	2.00	5.00	1.50	0.00
Englemann Daisy	2.00	5.00	2.50	0.00
Illinois Bundleflower	2.00	5.00	6.00	3.00
Sand Lovegrass	10.00	15.00	15.00	15.00
Sideoats Grama (El Reno)	5.00	6.00	6.00	10.00
Green Sprangletop	26.00	7.50	2.00	0.00
Not-planted species	4.13	38.16	67.00	72.00

Standard	11/12/04	4/20/05	8/1/05	10/28/05
V-cap	86.00	100.00	100.00	100.00
Little Bluestem	0.00	0.00	0.00	0.00
Blue Grama (Hachita)	0.00	0.00	0.00	0.00
Illinois Bundleflower	2.50	2.75	2.75	2.75
Sideoats Grama (Haskell)	33.50	49.00	49.00	35.00
Green Sprangletop	45.00	7.50	2.00	0.50
Common Bermuda	5.00	40.75	41.75	20.00
Not-planted species	0.00	0.00	4.50	41.75

* Non-native species: Common Bermuda


Plant ID Coverage: Indoor Clay Native, Austin
Coverage(%)
100
90
80
70
60
50
40
30
20
10
0
Nov-04
Jan-05
Mar-05
May-05
Jul-05
Sep-05
Nov-05
Not-planted species
Green Sprangletop
Sideoats Grama (El Reno)
Sand Lovegrass
Illinois Bundleflower
Englemann Daisy
Partridge Pea
Purple Three-Awn
Sand Dropseed
Buffalograss (Texoka)
Little Bluestem
Blue Grama (Hachita)


Plant ID Coverage: Indoor Clay Standard, Austin
Coverage(%)
100
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80
70
60
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20
10
0
Nov-04
Jan-05
Mar-05
May-05
Jul-05
Sep-05
Nov-05
Not-planted species
Common Bermuda
Green Sprangletop
Sideoats Grama (Haskell)
Illinois Bundleflower
Blue Grama (Hachita)
Little Bluestem

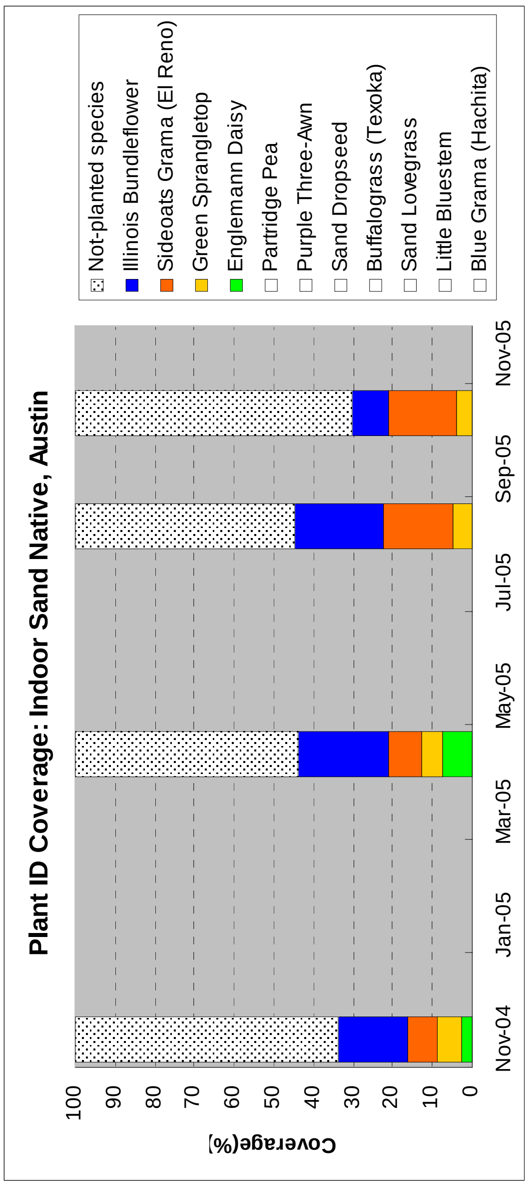
Austin Region

Indoor Sand

Native	11/12/04	4/20/05	8/1/05	10/28/05
V-cap	100.00	99.92	99.86	99.82
Blue Grama (Hachita)	0.00	0.00	0.00	0.00
Little Bluestem	0.00	0.00	0.00	0.00
Sand Lovegrass	0.00	0.00	0.00	0.00
Buffalograss (Texoka)	0.00	0.00	0.00	0.00
Sand Dropseed	0.00	0.00	0.00	0.00
Purple Three-Awn	0.00	0.00	0.00	0.00
Partridge Pea	0.00	0.00	0.00	0.00
Englemann Daisy	2.50	7.50	0.00	0.00
Green Sprangletop	6.25	5.25	4.75	3.75
Sideoats Grama (El Reno)	7.50	8.50	17.50	17.50
Illinois Bundleflower	17.50	22.50	22.50	9.00
Not-planted species	66.25	56.17	55.11	69.57

Standard	11/12/04	4/20/05	8/1/05	10/28/05
V-cap	90.77	96.48	99.87	99.83
Green Sprangletop	0.00	0.00	0.00	0.00
Partridge Pea	0.00	0.00	0.00	0.00
Sand Lovegrass	5.00	0.00	0.00	2.00
Weeping Love gr. (Ermelo)	52.50	52.50	52.50	57.50
Common Bermuda	0.00	2.50	3.00	3.00
Not-planted species	33.27	41.48	44.37	37.33

* Non-native species: Common Bermuda


Plant ID Coverage: Indoor Sand Native, Austin
Coverage(%)
100
90
80
70
60
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20
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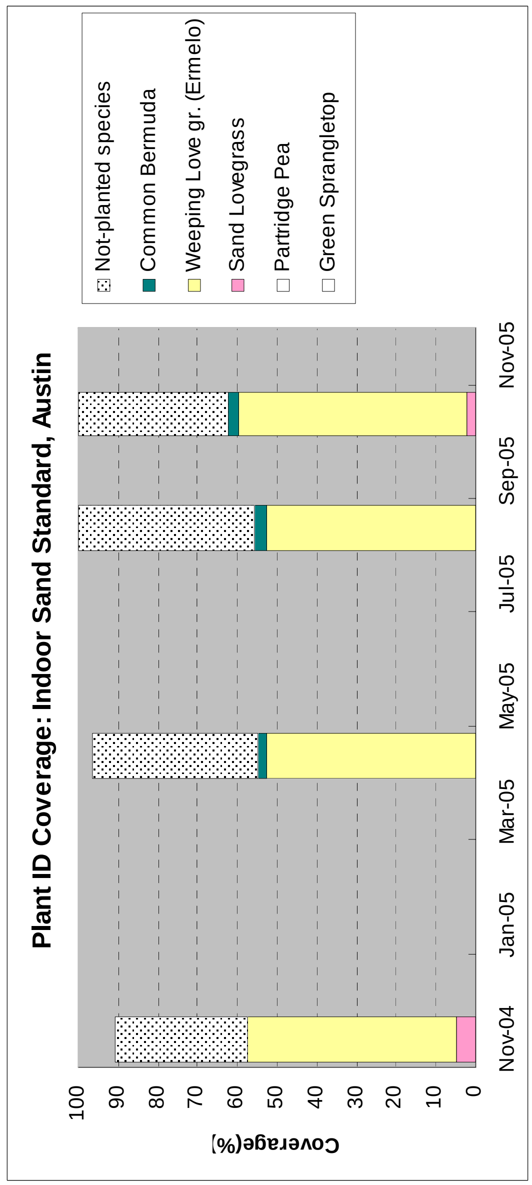
0
Nov-04
Jan-05
Mar-05
May-05
Jul-05
Sep-05
Nov-05
Not-planted species
Illinois Bundleflower
Sideoats Grama (El Reno)
Green Sprangletop
Englemann Daisy
Partridge Pea
Purple Three-Awn
Sand Dropseed
Buffalograss (Texoka)
Sand Lovegrass
Little Bluestem
Blue Grama (Hachita)


Plant ID Coverage: Indoor Sand Standard, Austin
Coverage(%)
100
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0
Nov-04
Jan-05
Mar-05
May-05
Jul-05
Sep-05
Nov-05
Not-planted species
Common Bermuda
Weeping Love gr. (Ermelo)
Sand Lovegrass
Partridge Pea
Green Sprangletop

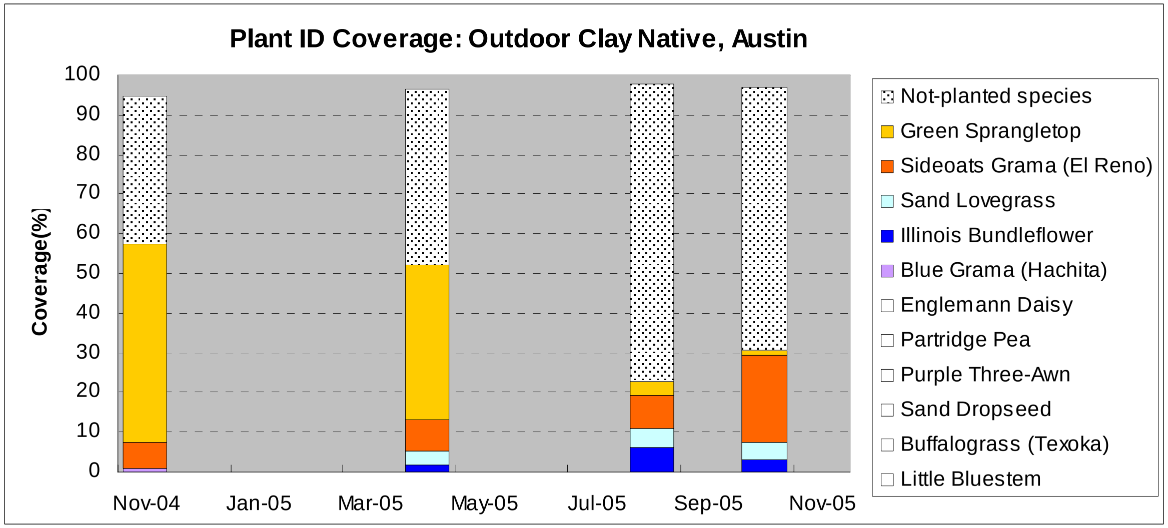
Austin Region

Outdoor Clay

Native	11/12/04	4/20/05	8/1/05	10/28/05
V-cap	94.63	96.50	97.70	96.93
Little Bluestem	0.00	0.00	0.00	0.00
Buffalograss (Texoka)	0.00	0.00	0.00	0.00
Sand Dropseed	0.00	0.00	0.00	0.00
Purple Three-Awn	0.00	0.00	0.00	0.00
Partridge Pea	0.00	0.00	0.00	0.00
Englemann Daisy	0.00	0.00	0.00	0.00
Blue Grama (Hachita)	0.83	0.00	0.00	0.00
Illinois Bundleflower	0.00	1.67	6.00	3.00
Sand Lovegrass	0.00	3.67	5.00	4.67
Sideoats Grama (El Reno)	6.67	7.67	8.33	21.67
Green Sprangletop	50.00	39.00	3.67	1.33
Not-planted species	37.13	44.50	74.70	66.26

Standard	11/12/04	4/20/05	8/1/05	10/28/05
V-cap	100.00	99.86	99.63	99.50
Little Bluestem	0.00	0.00	0.00	0.00
Blue Grama (Hachita)	0.00	0.00	0.00	0.00
Illinois Bundleflower	0.00	1.50	1.50	6.00
Sideoats Grama (Haskell)	21.33	24.00	25.00	25.00
Green Sprangletop	33.00	15.83	1.17	0.50
Common Bermuda	43.33	56.67	64.33	58.33
Not-planted species	2.33	1.86	7.63	9.67

* Non-native species: Common Bermuda


Plant ID Coverage: Outdoor Clay Native, Austin
Coverage(%)
100
90
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70
60
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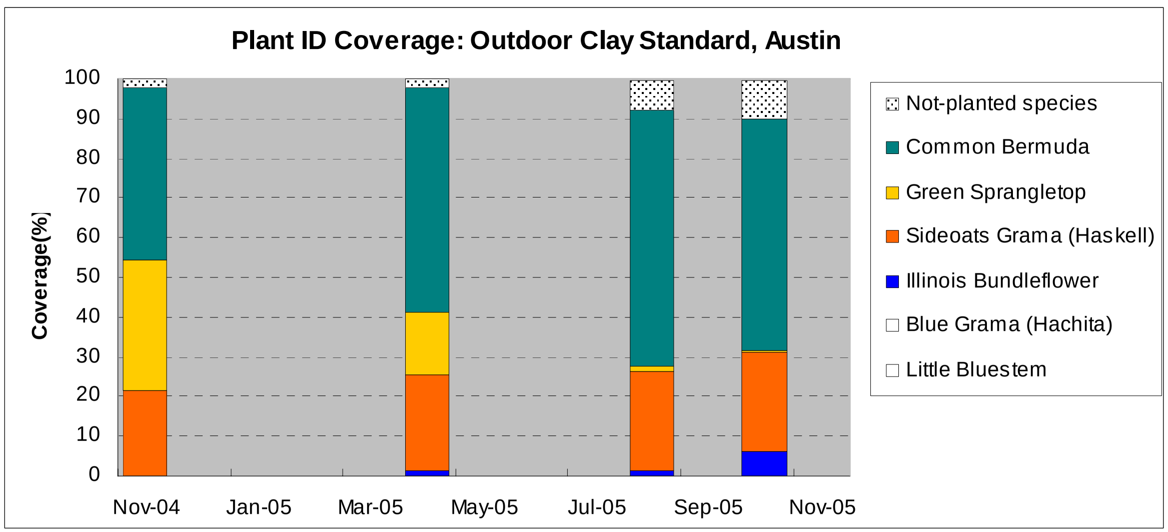
0
Nov-04
Jan-05
Mar-05
May-05
Jul-05
Sep-05
Nov-05
Not-planted species
Green Sprangletop
Sideoats Grama (El Reno)
Sand Lovegrass
Illinois Bundleflower
Blue Grama (Hachita)
Englemann Daisy
Partridge Pea
Purple Three-Awn
Sand Dropseed
Buffalograss (Texoka)
Little Bluestem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Coverage(%)
100
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Nov-04
Jan-05
Mar-05
May-05
Jul-05
Sep-05
Nov-05
Not-planted species
Common Bermuda
Green Sprangletop
Sideoats Grama (Haskell)
Illinois Bundleflower
Blue Grama (Hachita)
Little Bluestem

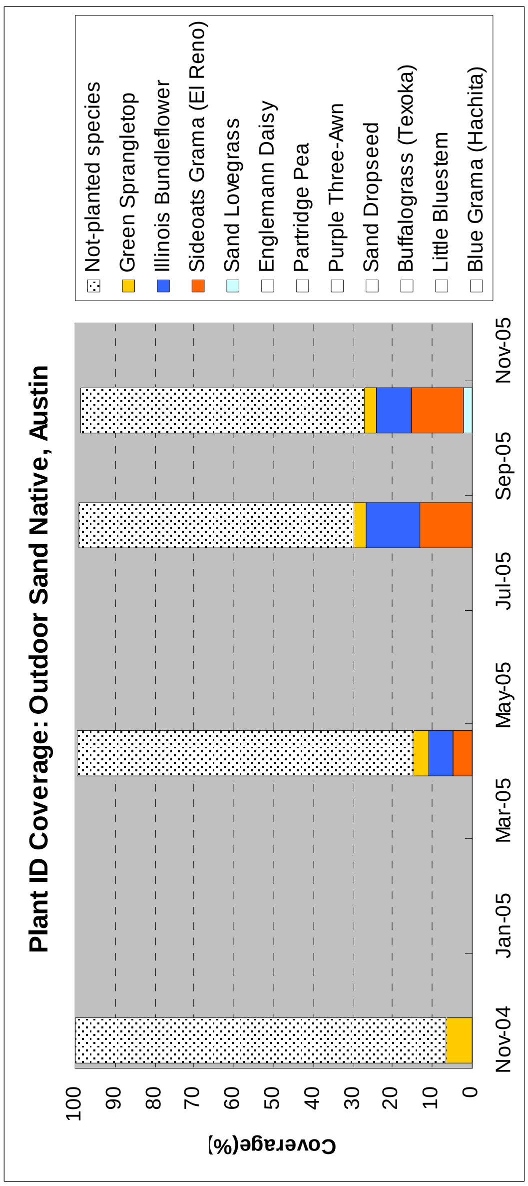
Austin Region

Outdoor Sand

Native	11/12/04	4/20/05	8/1/05	10/28/05
V-cap	100.00	99.41	99.02	98.70
Blue Grama (Hachita)	0.00	0.00	0.00	0.00
Little Bluestem	0.00	0.00	0.00	0.00
Buffalograss (Texoka)	0.00	0.00	0.00	0.00
Sand Dropseed	0.00	0.00	0.00	0.00
Purple Three-Awn	0.00	0.00	0.00	0.00
Partridge Pea	0.00	0.00	0.00	0.00
Englemann Daisy	0.00	0.00	0.00	0.00
Sand Lovegrass	0.00	0.00	0.00	2.00
Sideoats Grama (El Reno)	0.00	5.00	13.33	13.33
Illinois Bundleflower	0.00	6.00	13.33	8.67
Green Sprangletop	6.67	4.00	3.33	3.33
Not-planted species	93.33	84.41	69.02	71.36

Standard	11/12/04	4/20/05	8/1/05	10/28/05
V-cap	100.00	99.19	98.66	98.21
Sand Lovegrass	0.00	0.00	0.00	2.33
Partridge Pea	0.00	0.00	0.00	0.00
Weeping Love gr. (Ermelo)	0.00	2.33	6.67	6.67
Green Sprangletop	16.67	11.17	3.33	2.50
Common Bermuda	5.00	6.67	31.67	66.67
Not-planted species	78.33	79.02	57.00	20.05

* Non-native species: Common Bermuda


Plant ID Coverage: Outdoor Sand Native, Austin
Coverage(%)
100
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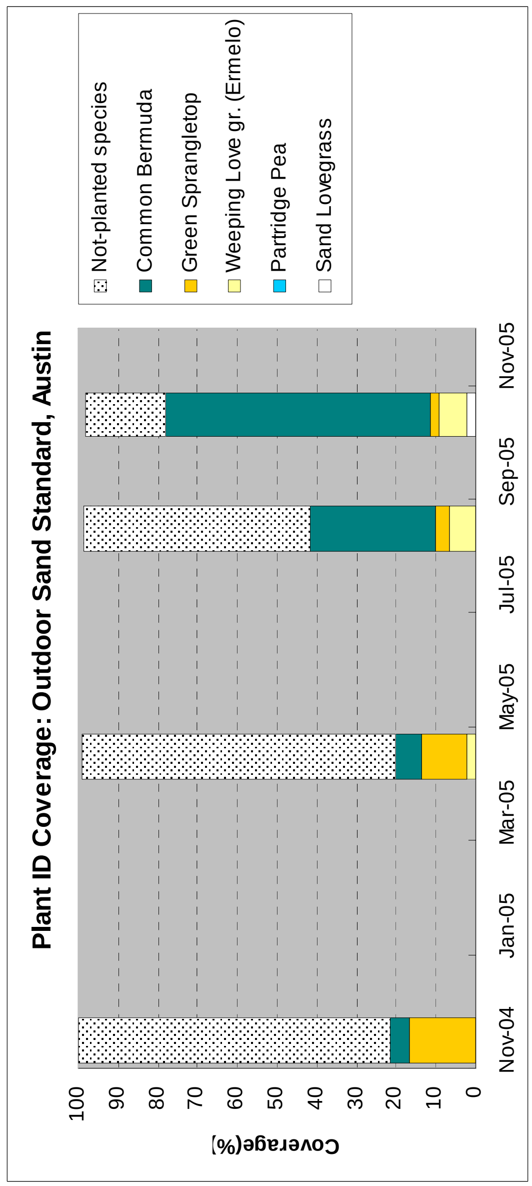
Nov-04
Jan-05
Mar-05
May-05
Jul-05
Sep-05
Nov-05
Not-planted species
Green Sprangletop
Illinois Bundleflower
Sideoats Grama (El Reno)
Sand Lovegrass
Englemann Daisy
Partridge Pea
Purple Three-Awn
Sand Dropseed
Buffalograss (Texoka)
Little Bluestem
Blue Grama (Hachita)


Plant ID Coverage: Outdoor Sand Standard, Austin
Coverage(%)
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Nov-04
Jan-05
Mar-05
May-05
Jul-05
Sep-05
Nov-05
Not-planted species
Common Bermuda
Green Sprangletop
Weeping Love gr. (Ermelo)
Partridge Pea
Sand Lovegrass

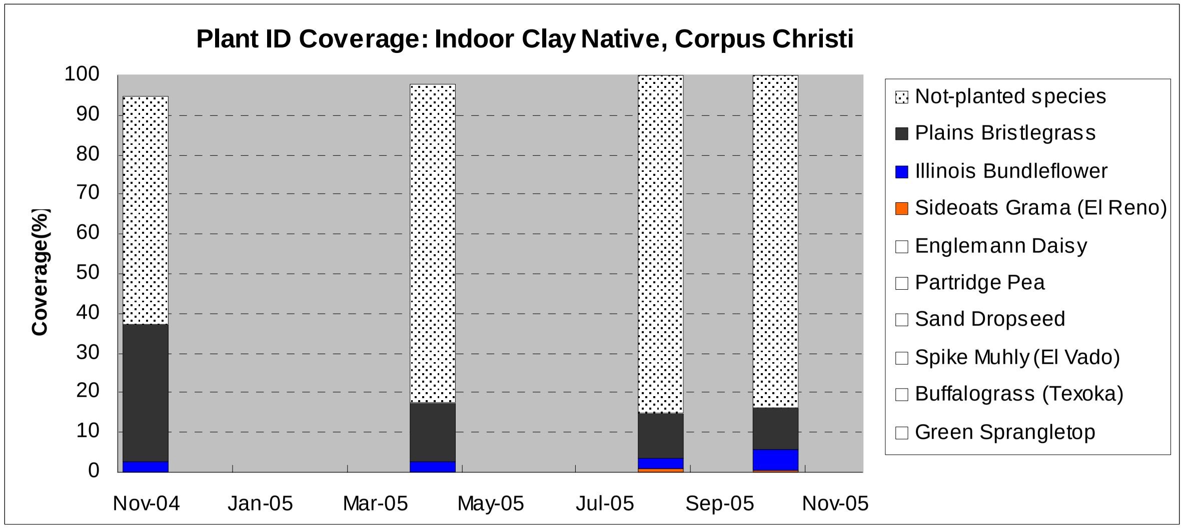
Corpus Christi

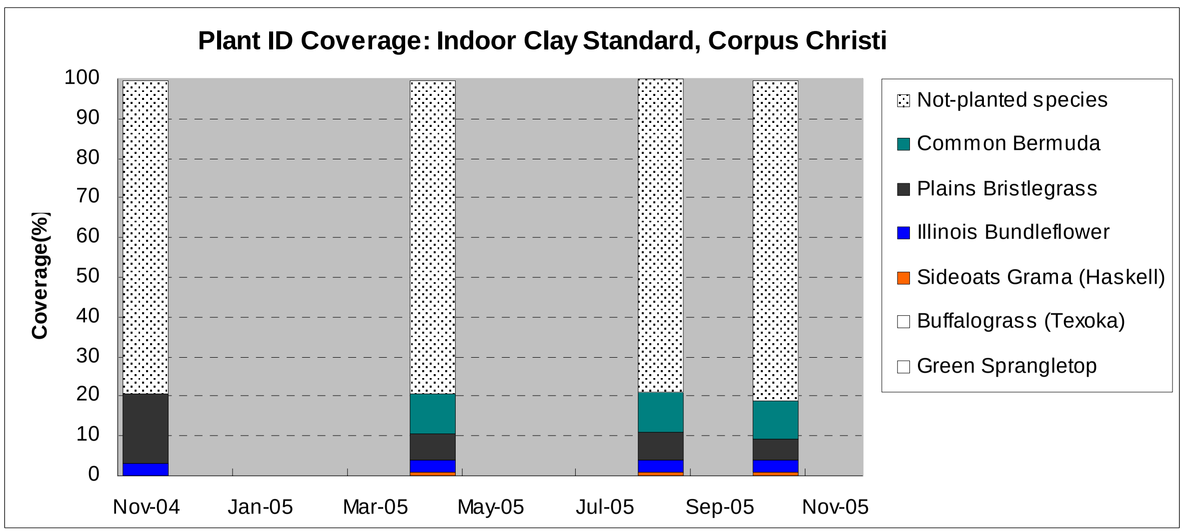
Indoor Clay

Native	11/12/04	4/20/05	8/1/05	10/28/05
V-cap	94.57	97.79	99.87	100.00
Green Sprangletop	0.00	0.00	0.00	0.00
Buffalograss (Texoka)	0.00	0.00	0.00	0.00
Spike Muhly (El Vado)	0.00	0.00	0.00	0.00
Sand Dropseed	0.00	0.00	0.00	0.00
Partridge Pea	0.00	0.00	0.00	0.00
Englemann Daisy	0.00	0.00	0.00	0.00
Sideoats Grama (El Reno)	0.00	0.00	1.00	0.50
Illinois Bundleflower	2.50	2.50	2.50	5.00
Plains Bristlegrass	35.00	15.00	11.25	10.75
Not-planted species	57.07	80.29	85.12	83.75

Standard	11/12/04	4/20/05	8/1/05	10/28/05
V-cap	99.47	99.55	99.85	99.65
Green Sprangletop	0.00	0.00	0.00	0.00
Buffalograss (Texoka)	0.00	0.00	0.00	0.00
Sideoats Grama (Haskell)	0.00	1.00	1.00	1.00
Illinois Bundleflower	3.00	3.00	3.00	3.00
Plains Bristlegrass	17.50	6.50	7.00	5.00
Common Bermuda	0.00	10.00	10.00	10.00
Not-planted species	78.97	79.05	78.85	80.65

* Non-native species: Common Bermuda


Plant ID Coverage: Indoor Clay Native, Corpus Christi
Coverage(%)
100
90
80
70
60
50
40
30
20
10
0
Nov-04
Jan-05
Mar-05
May-05
Jul-05
Sep-05
Nov-05
Not-planted species
Plains Bristlegrass
Illinois Bundleflower
Sideoats Grama (El Reno)
Englemann Daisy
Partridge Pea
Sand Dropseed
Spike Muhly (El Vado)
Buffalograss (Texoka)
Green Sprangletop


Plant ID Coverage: Indoor Clay Standard, Corpus Christi
Coverage(%)
100
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40
30
20
10
0
Nov-04
Jan-05
Mar-05
May-05
Jul-05
Sep-05
Nov-05
Not-planted species
Common Bermuda
Plains Bristlegrass
Illinois Bundleflower
Sideoats Grama (Haskell)
Buffalograss (Texoka)
Green Sprangletop

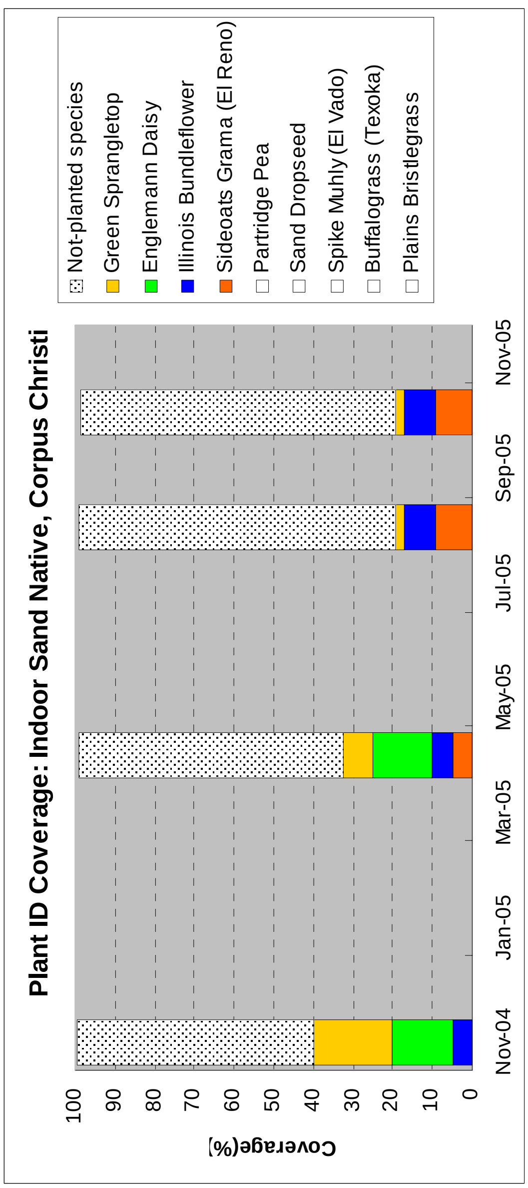
Corpus Christi

Indoor Sand

Native	11/12/04	4/20/05	8/1/05	10/28/05
V-cap	99.52	99.22	99.02	98.85
Plains Bristlegrass	0.00	0.00	0.00	0.00
Buffalograss (Texoka)	0.00	0.00	0.00	0.00
Spike Muhly (El Vado)	0.00	0.00	0.00	0.00
Sand Dropseed	0.00	0.00	0.00	0.00
Partridge Pea	0.00	0.00	0.00	0.00
Sideoats Grama (El Reno)	0.00	5.00	9.00	9.00
Illinois Bundleflower	5.00	5.00	8.25	8.25
Englemann Daisy	15.00	15.00	0.00	0.00
Green Sprangletop	20.00	7.50	2.00	2.00
Not-planted species	59.52	66.72	79.77	79.60

Standard	11/12/04	4/20/05	8/1/05	10/28/05
V-cap	97.55	97.88	98.54	98.67
Purple Prairieclover	0.00	0.00	0.00	0.00
Sand Lovegrass	2.50	2.50	0.00	0.00
Common Buffelgrass	5.00	4.75	0.00	0.00
Green Sprangletop	35.00	12.50	2.00	1.00
Common Bermuda	55.00	55.00	25.00	25.00
Not-planted species	0.05	23.13	71.54	72.67

* Non-native species: Common Bermuda


Plant ID Coverage: Indoor Sand Native, Corpus Christi
Coverage(%)
100
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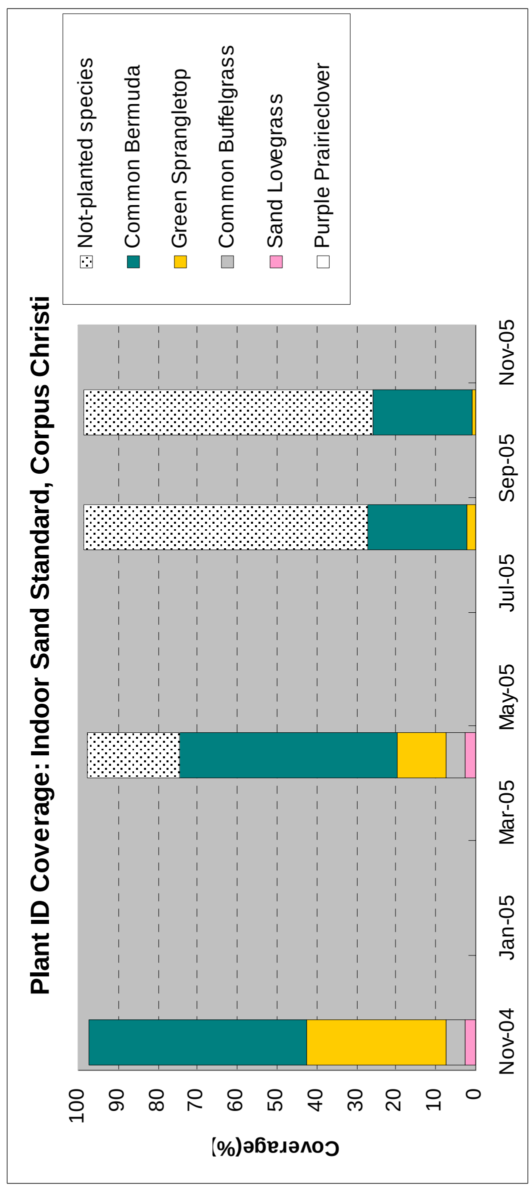
80
70
60
50
40
30
20
10
0
Nov-04
Jan-05
Mar-05
May-05
Jul-05
Sep-05
Nov-05
Not-planted species
Green Sprangletop
Englemann Daisy
Illinois Bundleflower
Sideoats Grama (El Reno)
Partridge Pea
Sand Dropseed
Spike Muhly(El Vado)
Buffalograss (Texoka)
Plains Bristlegrass


Plant ID Coverage: Indoor Sand Standard, Corpus Christi
Coverage(%)
100
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70
60
50
40
30
20
10
0
Nov-04
Jan-05
Mar-05
May-05
Jul-05
Sep-05
Nov-05
Not-planted species
Common Bermuda
Green Sprangletop
Common Buffelgrass
Sand Lovegrass
Purple Prairieclover

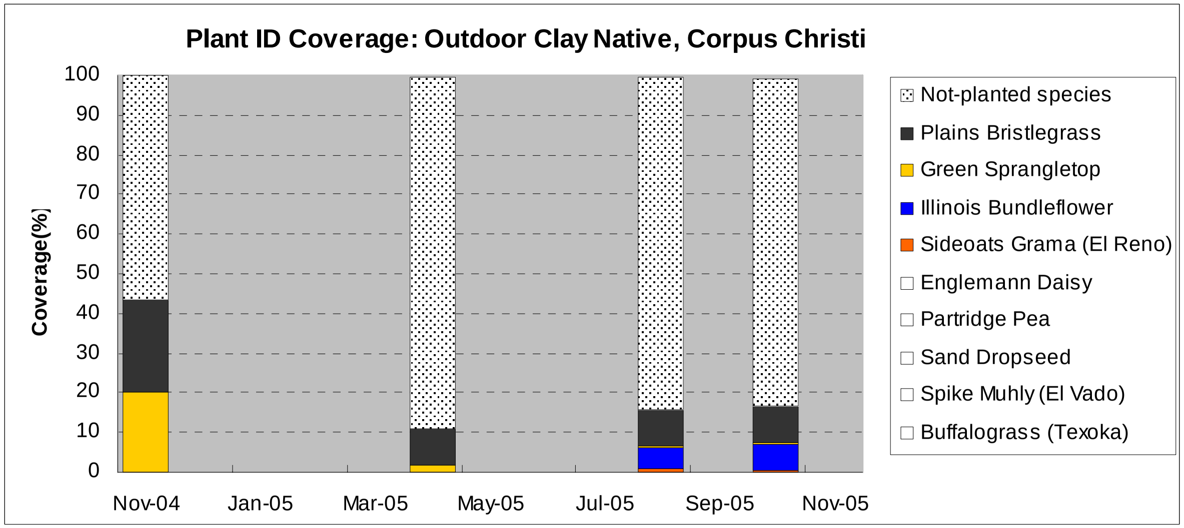
Corpus Christi

Outdoor Clay

Native	11/12/04	4/20/05	8/1/05	10/28/05
V-cap	100.00	99.70	99.51	99.34
Buffalograss (Texoka)	0.00	0.00	0.00	0.00
Spike Muhly (El Vado)	0.00	0.00	0.00	0.00
Sand Dropseed	0.00	0.00	0.00	0.00
Partridge Pea	0.00	0.00	0.00	0.00
Englemann Daisy	0.00	0.00	0.00	0.00
Sideoats Grama (El Reno)	0.00	0.00	1.00	0.33
Illinois Bundleflower	0.00	0.00	5.00	6.67
Green Sprangletop	20.00	1.67	0.77	0.67
Plains Bristlegrass	23.33	9.17	9.17	9.17
Not-planted species	56.67	88.87	83.57	82.51

Standard	11/12/04	4/20/05	8/1/05	10/28/05
V-cap	100.00	99.68	99.47	99.29
Buffalograss (Texoka)	0.00	0.00	0.00	0.00
Illinois Bundleflower	0.00	1.33	1.33	4.00
Sideoats Grama (Haskell)	0.00	1.83	2.83	1.00
Green Sprangletop	3.33	2.00	2.00	2.00
Plains Bristlegrass	40.00	11.00	13.67	13.33
Common Bermuda	6.67	13.33	54.33	65.00
Not-planted species	50.00	70.18	25.30	13.96

* Non-native species: Common Bermuda


Plant ID Coverage: Outdoor Clay Native, Corpus Christi
Coverage(%)
100
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70
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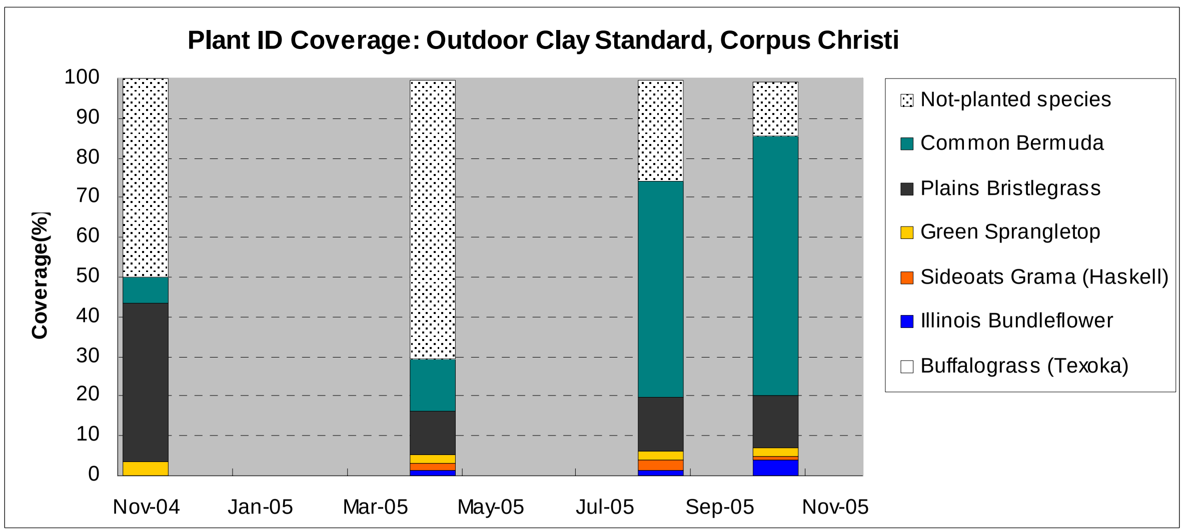
40
30
20
10
0
Nov-04
Jan-05
Mar-05
May-05
Jul-05
Sep-05
Nov-05
Not-planted species
Plains Bristlegrass
Green Sprangletop
Illinois Bundleflower
Sideoats Grama (El Reno)
Englemann Daisy
Partridge Pea
Sand Dropseed
Spike Muhly (El Vado)
Buffalograss (Texoka)


Plant ID Coverage: Outdoor Clay Standard, Corpus Christi
Coverage(%)
100
90
80
70
60
50
40
30
20
10
0
Nov-04
Jan-05
Mar-05
May-05
Jul-05
Sep-05
Nov-05
Not-planted species
Common Bermuda
Plains Bristlegrass
Green Sprangletop
Sideoats Grama (Haskell)
Illinois Bundleflower
Buffalograss (Texoka)

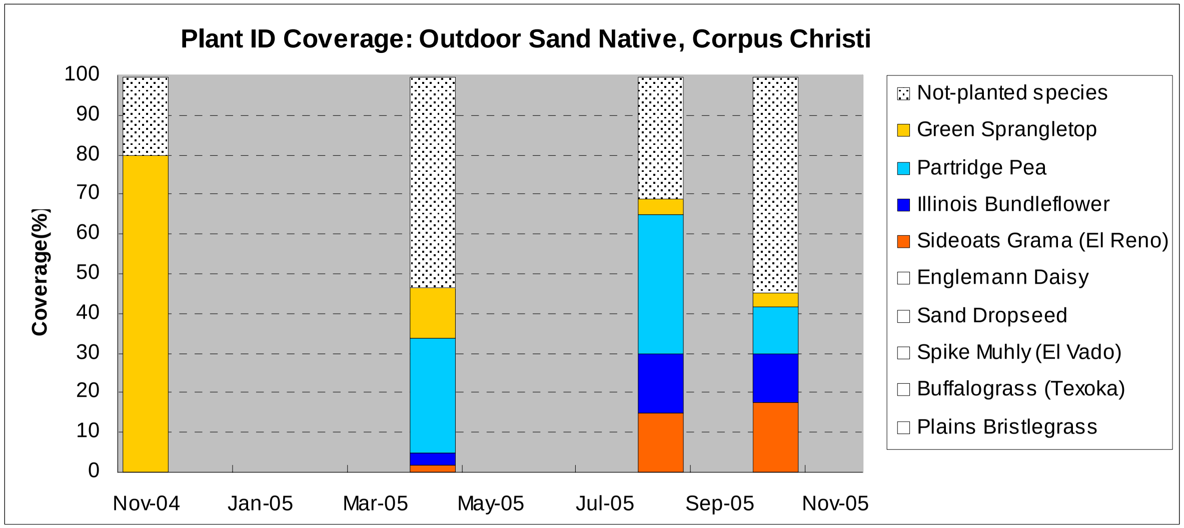
Corpus Christi

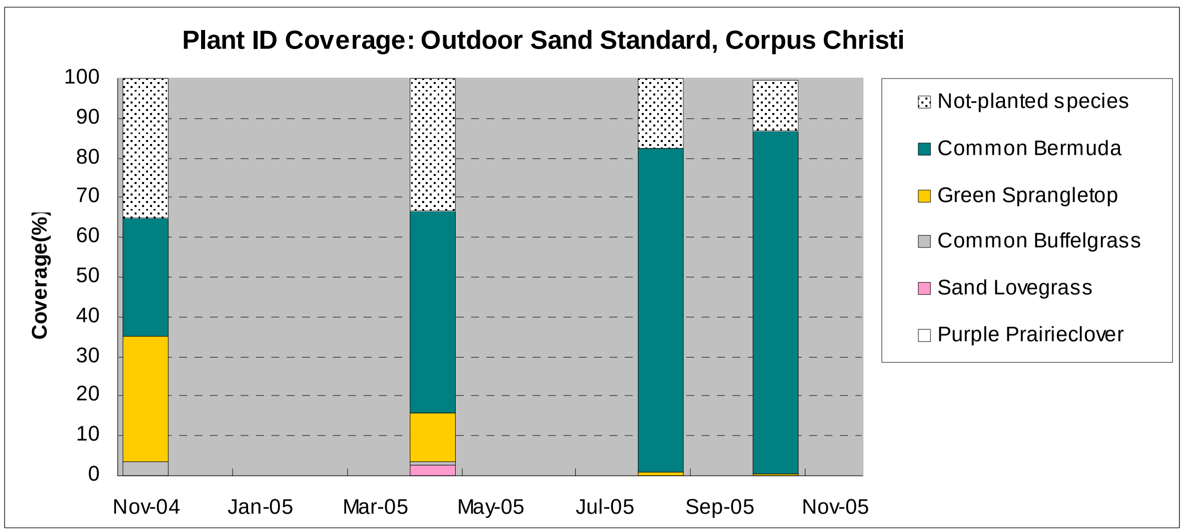
Outdoor Sand

Native	11/12/04	4/20/05	8/1/05	10/28/05
V-cap	99.45	99.57	99.64	99.70
Plains Bristlegrass	0.00	0.00	0.00	0.00
Buffalograss (Texoka)	0.00	0.00	0.00	0.00
Spike Muhly (El Vado)	0.00	0.00	0.00	0.00
Sand Dropseed	0.00	0.00	0.00	0.00
Englemann Daisy	0.00	0.00	0.00	0.00
Sideoats Grama (El Reno)	0.00	1.67	15.00	17.33
Illinois Bundleflower	0.00	3.33	15.00	12.67
Partridge Pea	0.00	28.67	35.00	11.67
Green Sprangletop	80.00	12.83	4.00	3.67
Not-planted species	19.45	53.07	30.64	54.37

Standard	11/12/04	4/20/05	8/1/05	10/28/05
V-cap	100.00	99.88	99.81	99.74
Purple Prairieclover	0.00	0.00	0.00	0.00
Sand Lovegrass	0.00	2.50	0.00	0.00
Common Buffelgrass	3.33	1.00	0.00	0.00
Green Sprangletop	31.67	12.33	0.67	0.33
Common Bermuda	30.00	51.00	81.67	86.67
Not-planted species	35.00	33.05	17.47	12.74

* Non-native species: Common Bermuda


Plant ID Coverage: Outdoor Sand Native, Corpus Christi
Coverage(%)
100
90
80
70
60
50
40
30
20
10
0
Nov-04
Jan-05
Mar-05
May-05
Jul-05
Sep-05
Nov-05
Not-planted species
Green Sprangletop
Partridge Pea
Illinois Bundleflower
Sideoats Grama (El Reno)
Englemann Daisy
Sand Dropseed
Spike Muhly (El Vado)
Buffalograss (Texoka)
Plains Bristlegrass


Plant ID Coverage: Outdoor Sand Standard, Corpus Christi
Coverage(%)
100
90
80
70
60
50
40
30
20
10
0
Nov-04
Jan-05
Mar-05
May-05
Jul-05
Sep-05
Nov-05
Not-planted species
Common Bermuda
Green Sprangletop
Common Buffelgrass
Sand Lovegrass
Purple Prairieclover

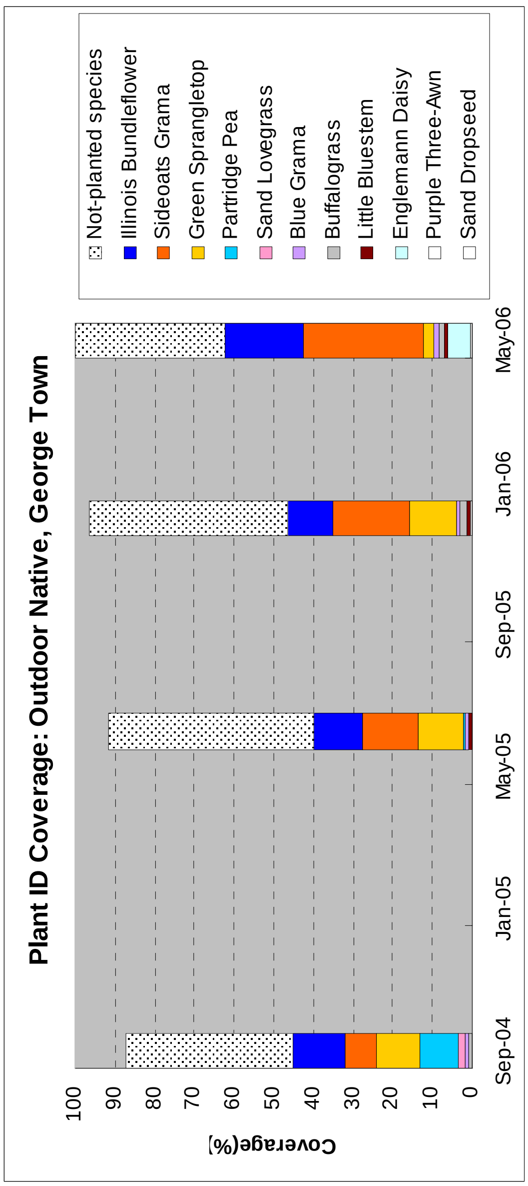
George Town

Outdoor

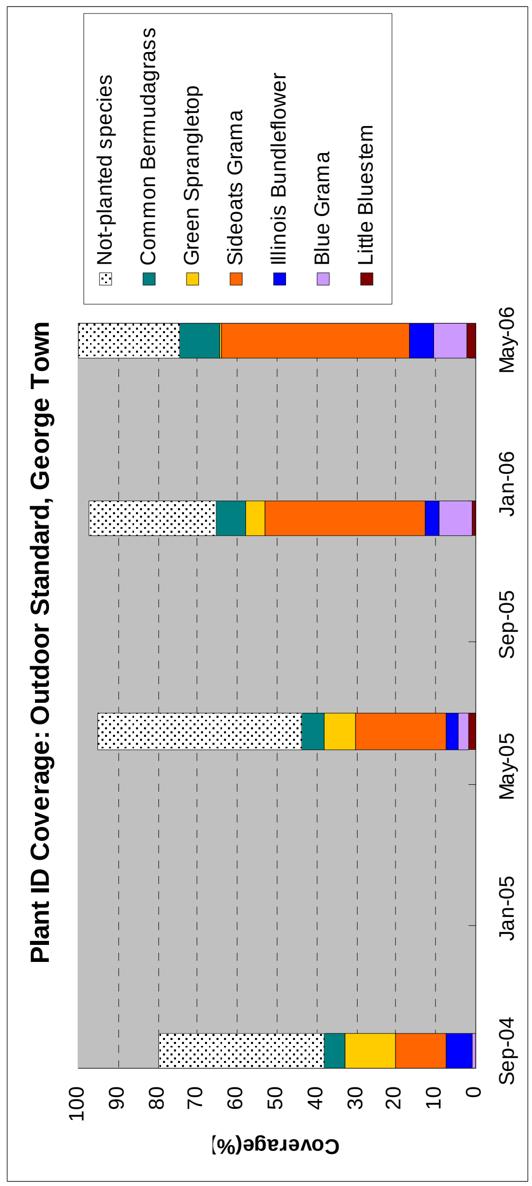
Native	9/14/04	6/23/05	12/7/05	5/4/06
V-cap	87.50	91.50	96.50	100.00
Sand Dropseed	0.00	0.00	0.00	0.00
Purple Three-Awn	0.00	0.00	0.48	0.50
Englemann Daisy	0.00	0.00	0.00	5.50
Little Bluestem	0.00	0.88	0.95	1.00
Buffalograss	0.85	0.00	1.47	1.50
Blue Grama	0.85	0.88	0.95	1.00
Sand Lovegrass	1.75	0.00	0.00	0.00
Partridge Pea	9.60	0.48	0.00	0.00
Green Sprangletop	10.88	11.35	12.03	3.00
Sideoats Grama	7.90	13.90	19.38	30.00
Illinois Bundleflower	13.25	12.48	11.15	20.00
Not-planted species	42.43	51.54	50.11	37.50

Standard	9/14/04	6/23/05	12/7/05	5/4/06
V-cap	80.00	95.00	97.50	100.00
Little Bluestem	0.00	1.87	0.98	2.00
Blue Grama	1.00	2.36	8.26	8.50
Illinois Bundleflower	6.50	3.37	3.42	6.00
Sideoats Grama	12.60	22.52	40.40	47.50
Green Sprangletop	13.00	8.12	4.88	0.50
Common Bermudagrass	5.00	5.73	7.32	10.00
Not-planted species	41.90	51.03	32.27	25.50

* Non-native species: Common Bermudagrass



Plant ID Coverage: Outdoor Native, George Town
Coverage(%)
100
90
80
70
60
50
40
30
20
10
0
Sep-04
Jan-05
May-05
Sep-05
Jan-06
May-06
Not-planted species
Illinois Bundleflower
Sideoats Grama
Green Sprangletop
Partridge Pea
Sand Lovegrass
Blue Grama
Buffalograss
Little Bluestem
Englemann Daisy
Purple Three-Awn
Sand Dropseed



Plant ID Coverage: Outdoor Standard, George Town
Coverage(%)
100
90
80
70
60
50
40
30
20
10
0
Sep-04
Jan-05
May-05
Sep-05
Jan-06
May-06
Not-planted species
Common Bermudagrass
Green Sprangletop
Sideoats Grama
Illinois Bundleflower
Blue Grama
Little Bluestem

Houston Region

Indoor Clay

District	2/9/06	6/6/06
V-cap	46.89	70.85
Sideoats Grama (Haskell)	0.00	0.00
Green Sprangletop	0.00	1.00
Little Bluestem (Native)	1.00	0.00
Foxtail Millet	12.50	0.00
Hulled Bermudagrass	0.00	40.00
Not-planted species	33.39	29.85

* Non-native species: Hulled Bermudagrass

Standard	2/9/06	6/6/06
V-cap	43.46	54.31
Green Sprangletop	0.00	0.00
Sideoats Grama (Haskell)	1.00	0.00
Common Bermudagrass	5.00	30.00
Not-planted species	37.46	24.31

* Non-native speccies: Common Bermudagrass

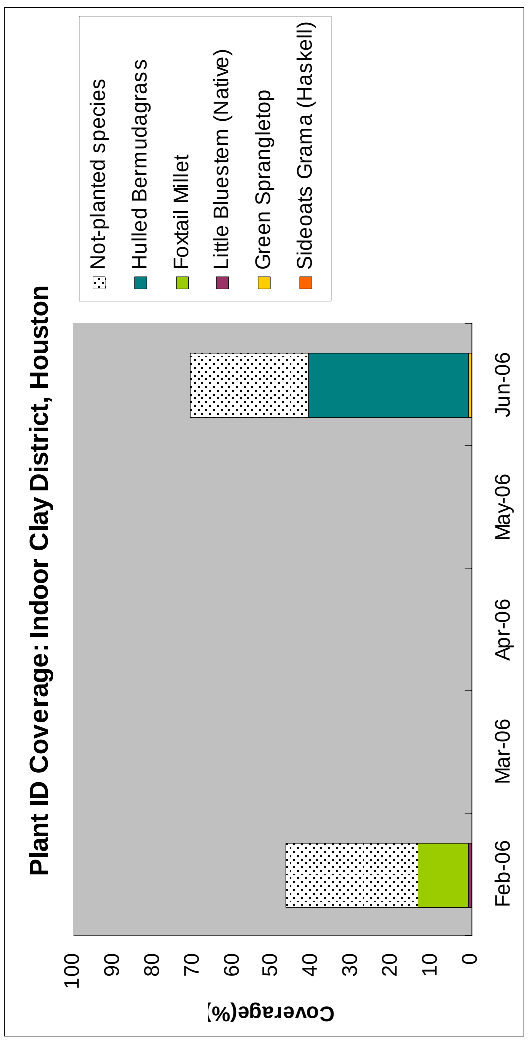
Indoor Sand

District	2/9/06	6/6/06
V-cap	76.56	95.11
Sideoats Grama (Haskell)	0.00	0.00
Green Sprangletop	0.00	0.00
Little Bluestem (Native)	0.00	0.00
Foxtail Millet	5.00	0.00
Hulled Bermudagrass	0.00	1.00
Not-planted species	71.56	94.11

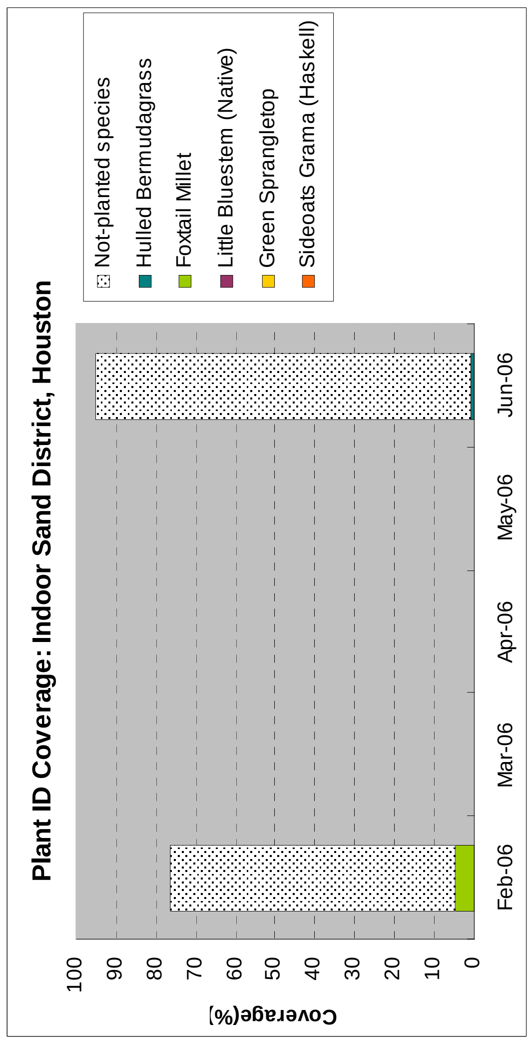
* Non-native species: Hulled Bermudagrass

Standard	2/9/06	6/6/06
V-cap	70.76	98.51
Green Sprangletop	0.00	0.00
Common Bermudagrass	0.00	2.00
Not-planted species	70.76	96.51

* Non-native speccies: Common Bermudagrass



Plant ID Coverage: Indoor Clay District, Houston
Coverage(%)
100
90
80
70
60
50
40
30
20
10
0
Feb-06
Mar-06
Apr-06
May-06
Jun-06
Not-planted species
Hulled Bermudagrass
Foxtail Millet
Little Bluestem (Native)
Green Sprangletop
Sideoats Grama (Haskell)



Plant ID Coverage: Indoor Sand District, Houston
Coverage(%)
100
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70
60
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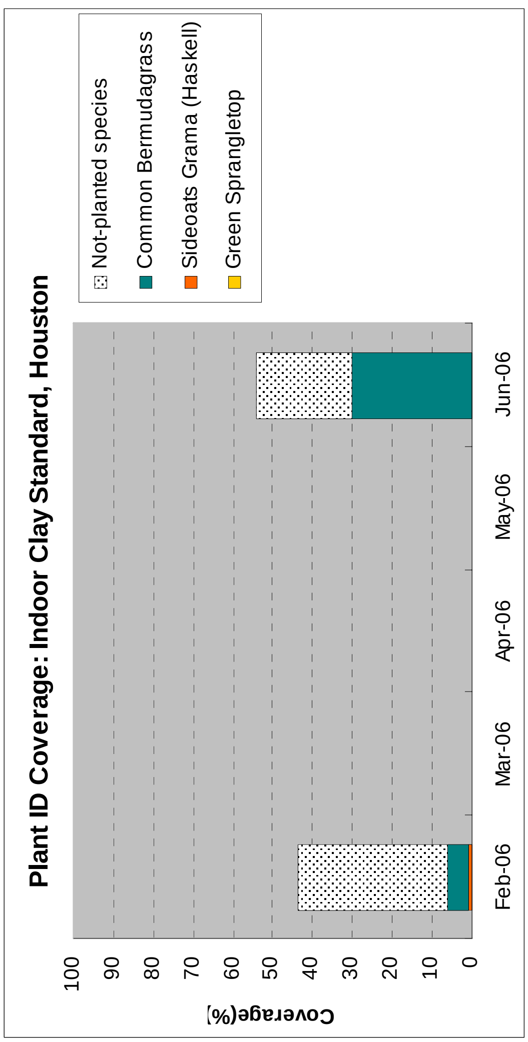
40
30
20
10
0
Feb-06
Mar-06
Apr-06
May-06
Jun-06
Not-planted species
Hulled Bermudagrass
Foxtail Millet
Little Bluestem (Native)
Green Sprangletop
Sideoats Grama (Haskell)


Plant ID Coverage: Indoor Clay Standard, Houston
Not-planted species
Common Bermudagrass
Sideoats Grama (Haskell)
Green Sprangletop
Coverage(%)
100
90
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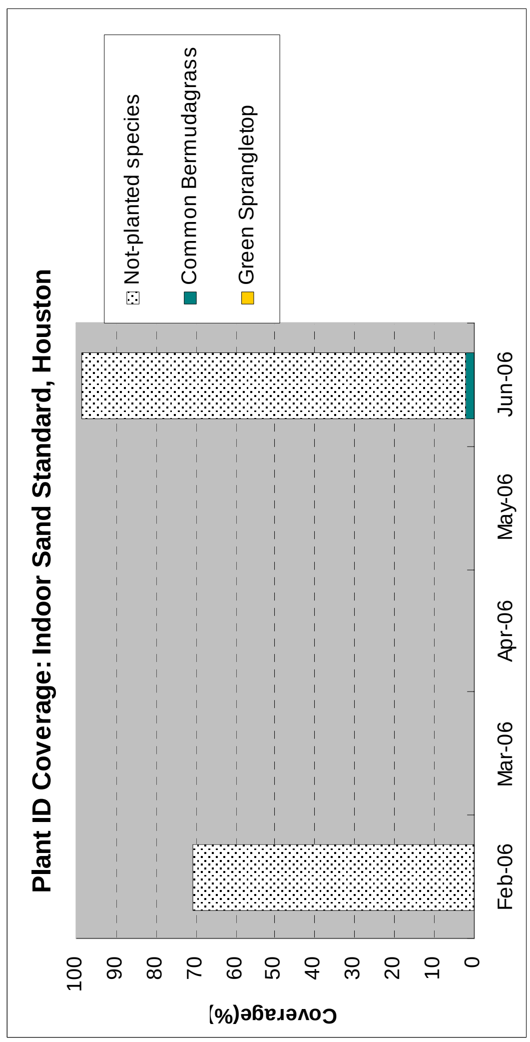
70
60
50
40
30
20
10
0
Feb-06
Mar-06
Apr-06
May-06
Jun-06


Plant ID Coverage: Indoor Sand Standard, Houston
Not-planted species
Common Bermudagrass
Green Sprangletop
Coverage(%)
100
90
80
70
60
50
40
30
20
10
0
Feb-06
Mar-06
Apr-06
May-06
Jun-06

Houston Region

Outdoor Clay

District	2/9/06	6/6/06
V-cap	2.44	98.38
Little Bluestem (Native)	0.00	0.00
Foxtail Millet	0.00	0.00
Sideoats Grama (Haskell)	0.00	2.00
Green Sprangletop	0.00	3.67
Hulled Bermudagrass	0.00	88.33
Not-planted species	2.44	4.38

* Non-native species: Hulled Bermudagrass

Standard	2/9/06	6/6/06
V-cap	1.28	30.54
Sideoats Grama (Haskell)	0.00	0.00
Green Sprangletop	0.00	0.33
Common Bermudagrass	0.00	6.33
Not-planted species	1.28	23.87

* Non-native speccies: Common Bermudagrass

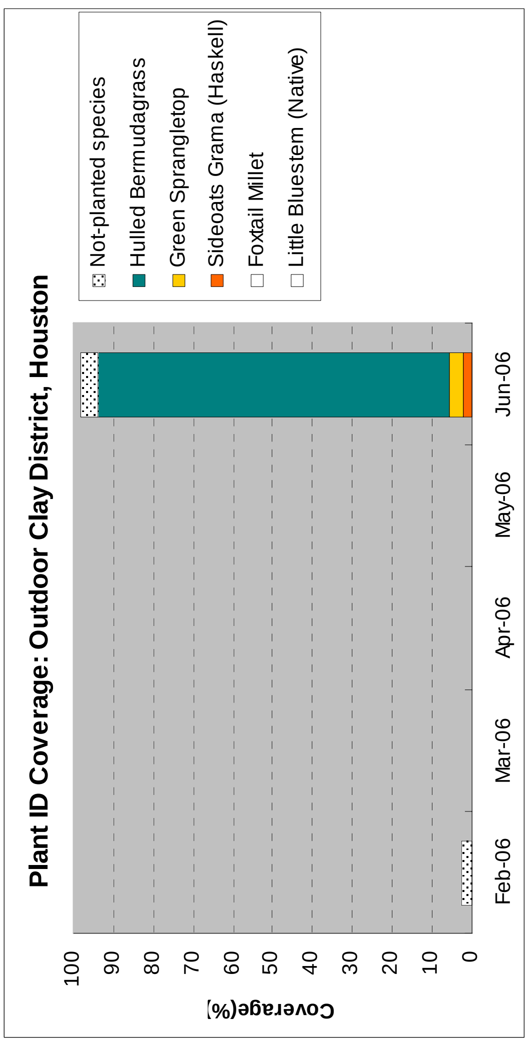
Outdoor Sand

District	2/9/06	6/6/06
V-cap	37.03	100.00
Little Bluestem (Native)	0.00	0.00
Foxtail Millet	0.00	0.00
Sideoats Grama (Haskell)	0.00	0.00
Green Sprangletop	0.00	0.00
Hulled Bermudagrass	0.00	2.33
Not-planted species	37.03	97.67

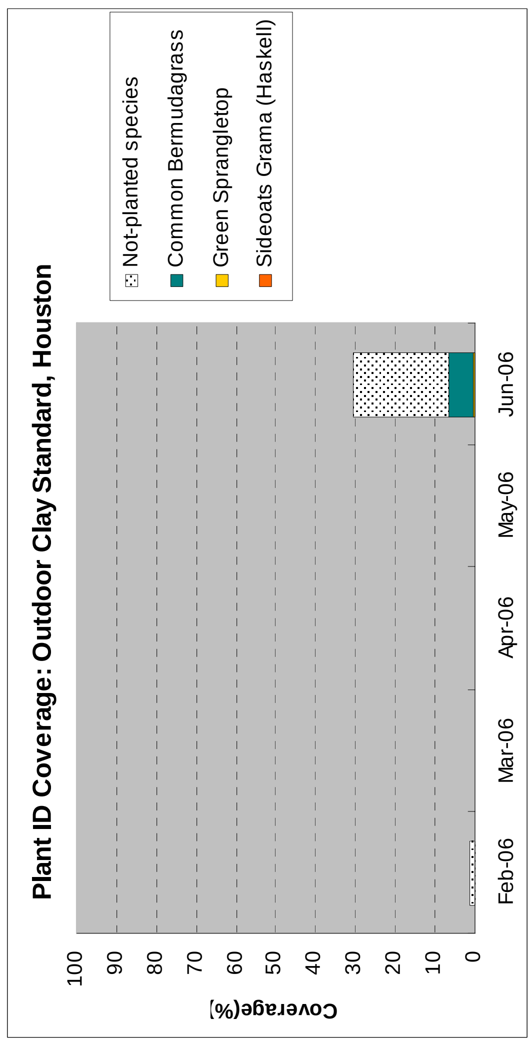
* Non-native species: Hulled Bermudagrass

Standard	2/9/06	6/6/06
V-cap	40.17	98.50
Green Sprangletop	0.00	0.00
Common Bermudagrass	0.00	0.67
Not-planted species	40.17	97.84

* Non-native speccies: Common Bermudagrass



Plant ID Coverage: Outdoor Clay District, Houston
Coverage(%)
100
90
80
70
60
50
40
30
20
10
0
Feb-06
Mar-06
Apr-06
May-06
Jun-06
Not-planted species
Hulled Bermudagrass
Green Sprangletop
Sideoats Grama (Haskell)
Foxtail Millet
Little Bluestem (Native)



Plant ID Coverage: Outdoor Clay Standard, Houston
Coverage(%)
100
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60
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40
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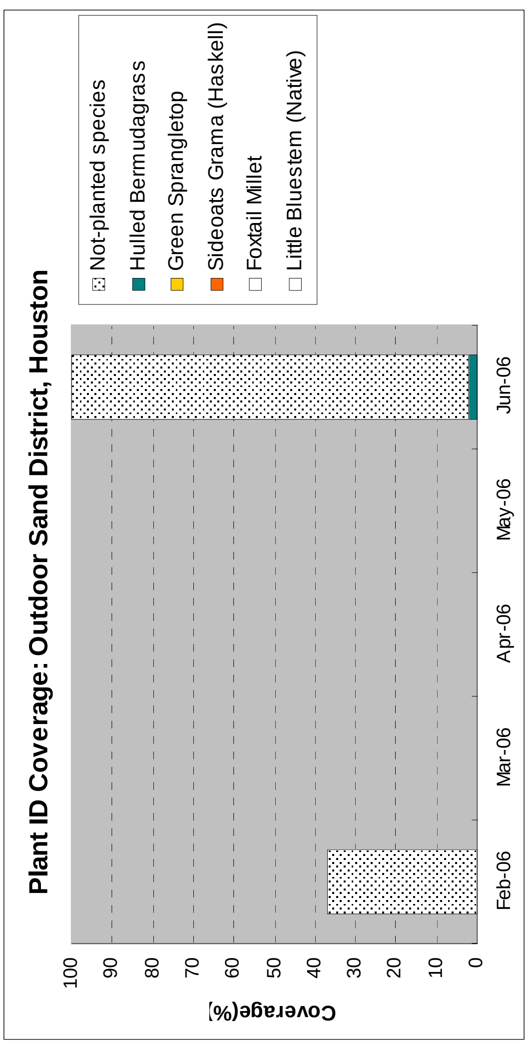
20
10
0
Feb-06
Mar-06
Apr-06
May-06
Jun-06
Not-planted species
Common Bermudagrass
Green Sprangletop
Sideoats Grama (Haskell)


Plant ID Coverage: Outdoor Sand District, Houston
Coverage(%)
100
90
80
70
60
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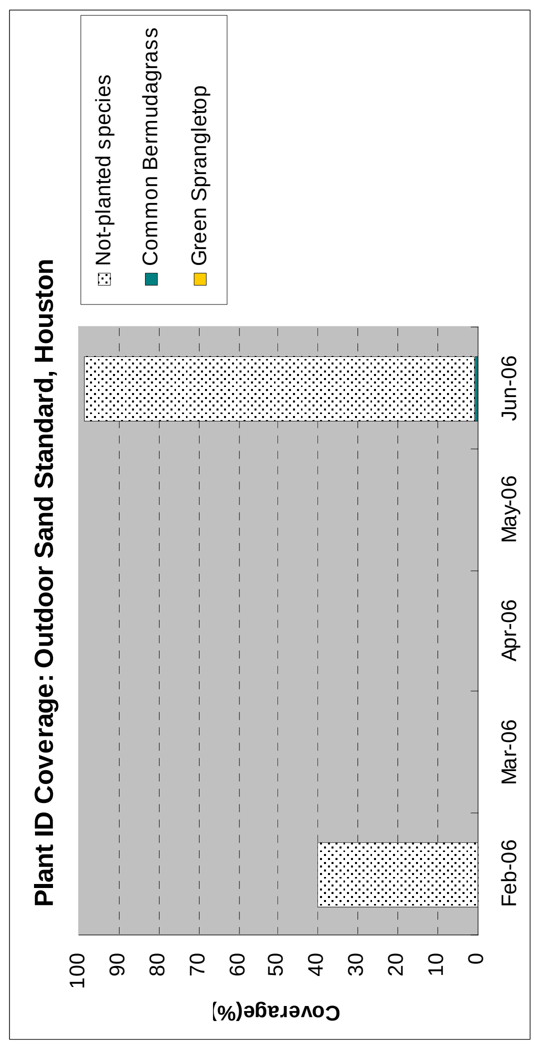
40
30
20
10
0
Feb-06
Mar-06
Apr-06
May-06
Jun-06
Not-planted species
Hulled Bermudagrass
Green Sprangletop
Sideoats Grama (Haskell)
Foxtail Millet
Little Bluestem (Native)


Plant ID Coverage: Outdoor Sand Standard, Houston
Coverage(%)
100
90
80
70
60
50
40
30
20
10
0
Feb-06
Mar-06
Apr-06
May-06
Jun-06
Not-planted species
Common Bermudagrass
Green Sprangletop

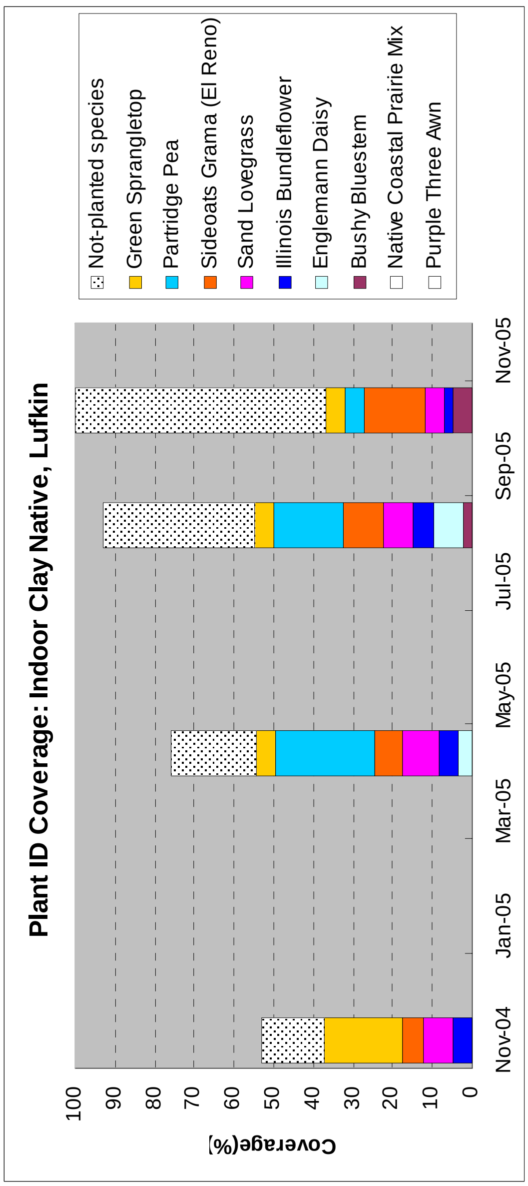
Lufkin Region

Indoor Clay

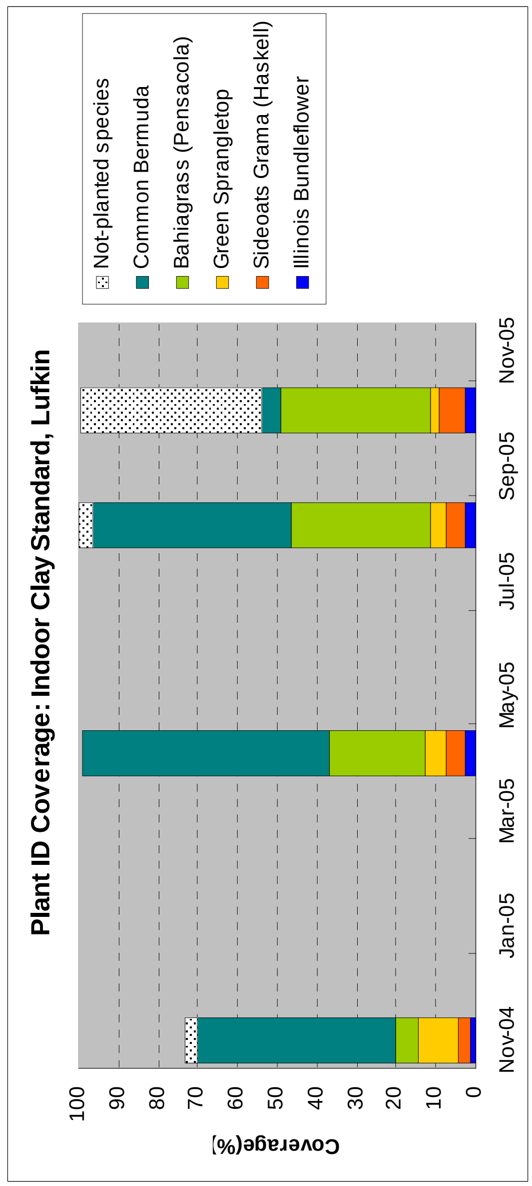
Native	11/12/04	4/20/05	8/1/05	10/28/05
V-cap	53.02	76.03	93.11	100.00
Purple Three Awn	0.00	0.00	0.00	0.00
Native Coastal Prairie Mix	0.00	0.00	0.00	0.00
Bushy Bluestem	0.00	0.00	2.00	5.00
Englemann Daisy	0.00	3.50	7.50	0.00
Illinois Bundleflower	5.00	5.00	5.50	2.00
Sand Lovegrass	7.50	9.25	7.50	5.00
Sideoats Grama (El Reno)	5.00	6.75	10.00	15.00
Partridge Pea	0.00	25.00	17.50	5.00
Green Sprangletop	20.00	5.00	5.00	5.00
Not-planted species	15.52	21.53	38.11	63.00

Standard	11/12/04	4/20/05	8/1/05	10/28/05
V-cap	73.07	99.25	100.00	99.61
Illinois Bundleflower	1.50	2.50	2.50	2.50
Sideoats Grama (Haskell)	3.00	5.00	5.00	6.50
Green Sprangletop	10.00	5.25	4.00	2.50
Bahiagrass (Pensacola)	5.50	24.00	35.00	37.50
Common Bermuda	50.00	62.50	50.00	5.00
Not-planted species	3.07	0.00	3.50	45.61

* Non-native species: Common Bermuda, Bahiagrass



Plant ID Coverage: Indoor Clay Native, Lufkin
Coverage(%)
0
10
20
30
40
50
60
70
80
90
100
Nov-04
Jan-05
Mar-05
May-05
Jul-05
Sep-05
Nov-05
Not-planted species
Green Sprangletop
Partridge Pea
Sideoats Grama (El Reno)
Sand Lovegrass
Illinois Bundleflower
Englemann Daisy
Bushy Bluestem
Native Coastal Prairie Mix
Purple Three Awn



Plant ID Coverage: Indoor Clay Standard, Lufkin
Coverage(%)
0
10
20
30
40
50
60
70
80
90
100
Nov-04
Jan-05
Mar-05
May-05
Jul-05
Sep-05
Nov-05
Not-planted species
Common Bermuda
Bahiagrass (Pensacola)
Green Sprangletop
Sideoats Grama (Haskell)
Illinois Bundleflower

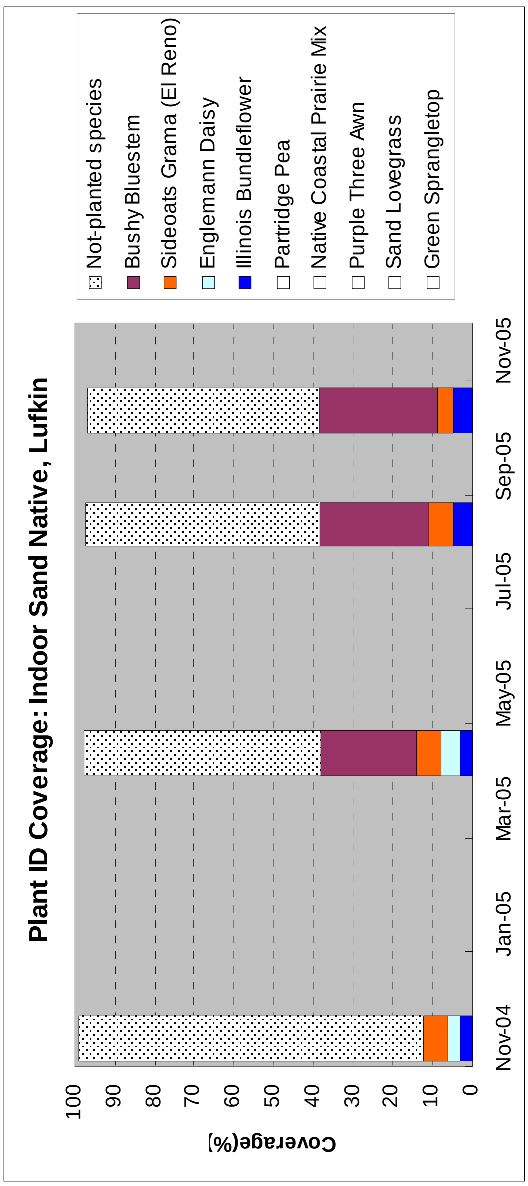
Lufkin Region

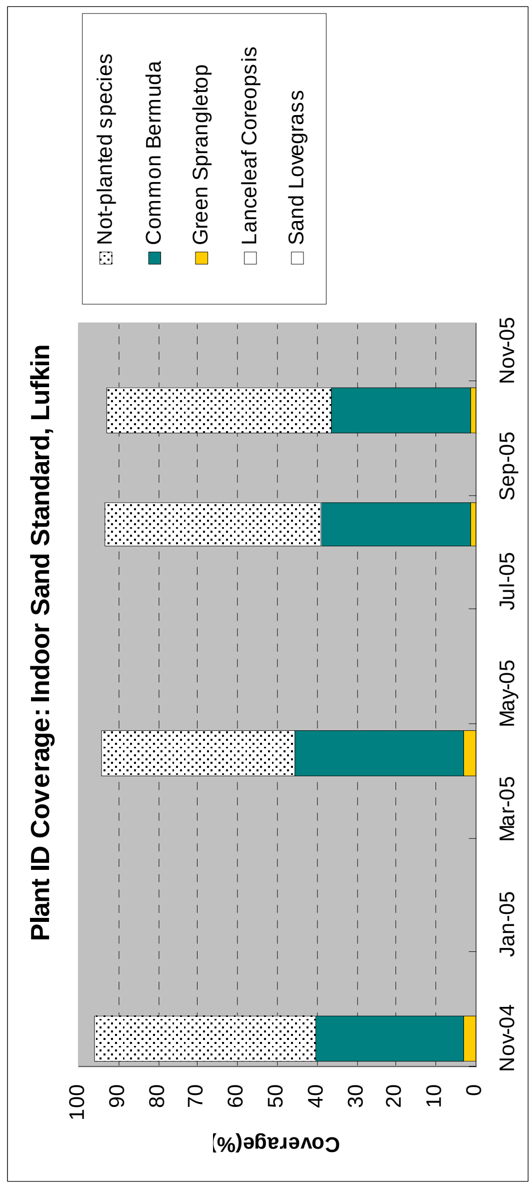
Indoor Sand

Native	11/12/04	4/20/05	8/1/05	10/28/05
V-cap	99.02	97.99	97.32	96.75
Green Sprangletop	0.00	0.00	0.00	0.00
Sand Lovegrass	0.00	0.00	0.00	0.00
Purple Three Awn	0.00	0.00	0.00	0.00
Native Coastal Prairie Mix	0.00	0.00	0.00	0.00
Partridge Pea	0.00	0.00	0.00	0.00
Illinois Bundleflower	3.00	3.00	5.00	5.00
Englemann Daisy	3.00	5.00	0.00	0.00
Sideoats Grama (El Reno)	6.25	6.00	6.00	3.75
Bushy Bluestem	0.00	24.00	27.50	30.00
Not-planted species	86.77	59.99	58.82	58.00

Standard	11/12/04	4/20/05	8/1/05	10/28/05
V-cap	96.20	98.21	99.51	99.37
Sand Lovegrass	0.00	0.00	0.00	0.00
Lanceleaf Coreopsis	0.00	0.00	0.00	0.00
Green Sprangletop	3.00	3.00	1.50	1.50
Bahiagrass (Pensacola)	0.00	3.75	6.25	6.25
Common Bermuda	37.50	42.50	37.50	35.00
Not-planted species	55.70	48.96	54.26	56.62

* Non-native species: Common Bermuda, Bahiagrass


Plant ID Coverage: Indoor Sand Native, Lufkin
Coverage(%)
100
90
80
70
60
50
40
30
20
10
0
Nov-04
Jan-05
Mar-05
May-05
Jul-05
Sep-05
Nov-05
Not-planted species
Bushy Bluestem
Sideoats Grama (El Reno)
Englemann Daisy
Illinois Bundleflower
Partridge Pea
Native Coastal Prairie Mix
Purple Three Awn
Sand Lovegrass
Green Sprangletop


Plant ID Coverage: Indoor Sand Standard, Lufkin
Coverage(%)
100
90
80
70
60
50
40
30
20
10
0
Nov-04
Jan-05
Mar-05
May-05
Jul-05
Sep-05
Nov-05
Not-planted species
Common Bermuda
Green Sprangletop
Lanceleaf Coreopsis
Sand Lovegrass

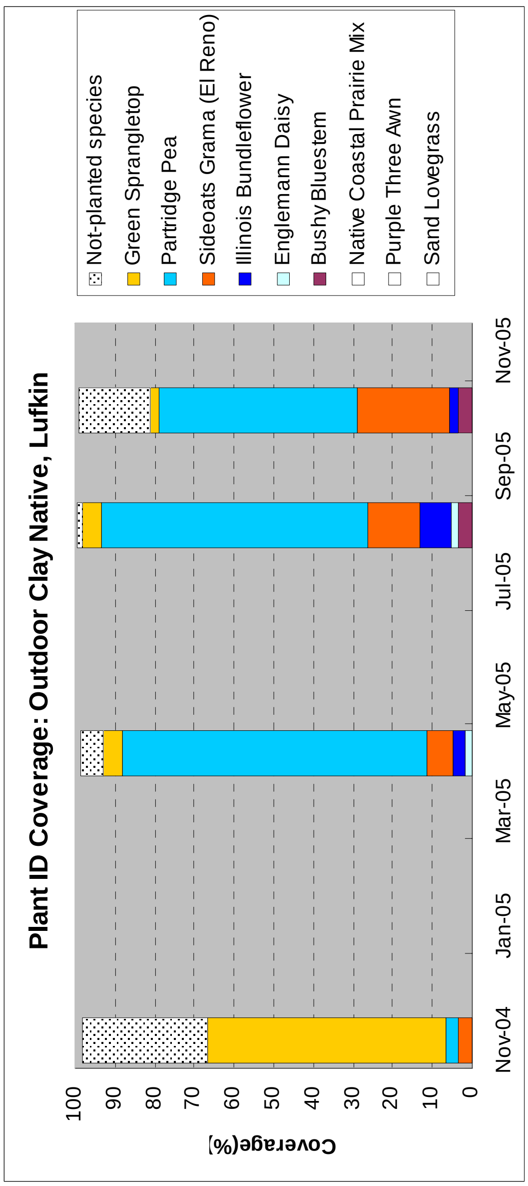
Lufkin Region

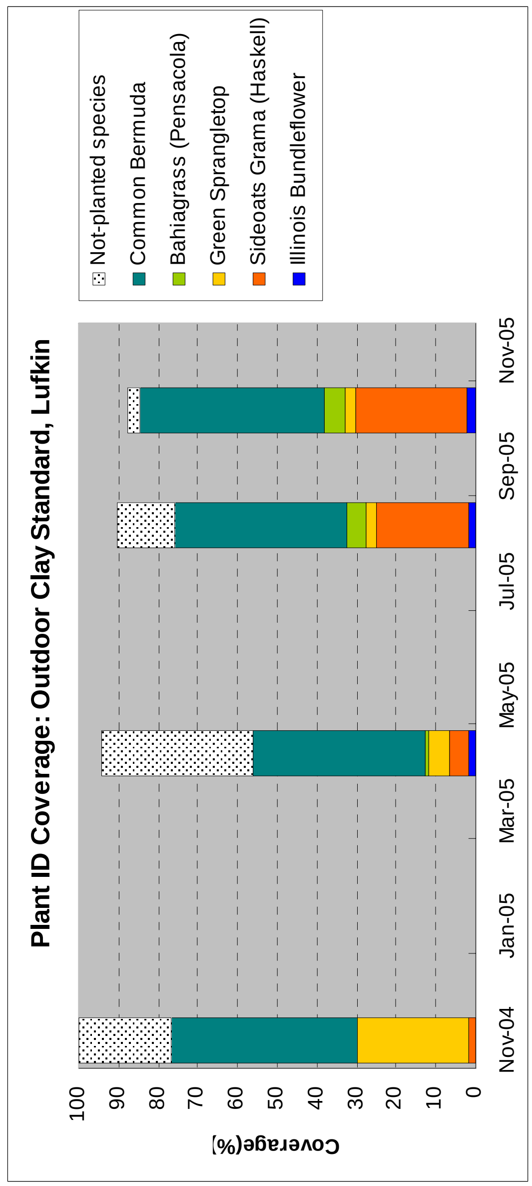
Outdoor Clay

Native	11/12/04	4/20/05	8/1/05	10/28/05
V-cap	98.42	98.68	99.53	99.00
Sand Lovegrass	0.00	0.00	0.00	0.00
Purple Three Awn	0.00	0.00	0.00	0.00
Native Coastal Prairie Mix	0.00	0.00	0.00	0.00
Bushy Bluestem	0.00	0.00	3.67	3.67
Englemann Daisy	0.00	1.83	1.67	0.00
Illinois Bundleflower	0.00	2.83	8.00	2.00
Sideoats Grama (El Reno)	3.33	6.67	13.17	23.33
Partridge Pea	3.33	76.67	66.83	50.00
Green Sprangletop	60.00	5.00	5.00	2.00
Not-planted species	31.75	5.68	1.20	18.00

Standard	11/12/04	4/20/05	8/1/05	10/28/05
V-cap	100.00	94.21	90.46	87.91
Illinois Bundleflower	0.00	1.67	1.67	2.00
Sideoats Grama (Haskell)	1.67	5.00	23.33	28.33
Green Sprangletop	28.33	5.00	2.50	2.67
Bahiagrass (Pensacola)	0.00	1.08	5.00	5.00
Common Bermuda	46.67	43.33	43.33	46.67
Not-planted species	23.33	38.13	14.63	3.24

* Non-native species: Common Bermuda, Bahiagrass


Plant ID Coverage: Outdoor Clay Native, Lufkin
Coverage(%)
100
90
80
70
60
50
40
30
20
10
0
Nov-04
Jan-05
Mar-05
May-05
Jul-05
Sep-05
Nov-05
Not-planted species
Green Sprangletop
Partridge Pea
Sideoats Grama (El Reno)
Illinois Bundleflower
Englemann Daisy
Bushy Bluestem
Native Coastal Prairie Mix
Purple Three Awn
Sand Lovegrass


Plant ID Coverage: Outdoor Clay Standard, Lufkin
Coverage(%)
100
90
80
70
60
50
40
30
20
10
0
Nov-04
Jan-05
Mar-05
May-05
Jul-05
Sep-05
Nov-05
Not-planted species
Common Bermuda
Bahiagrass (Pensacola)
Green Sprangletop
Sideoats Grama (Haskell)
Illinois Bundleflower

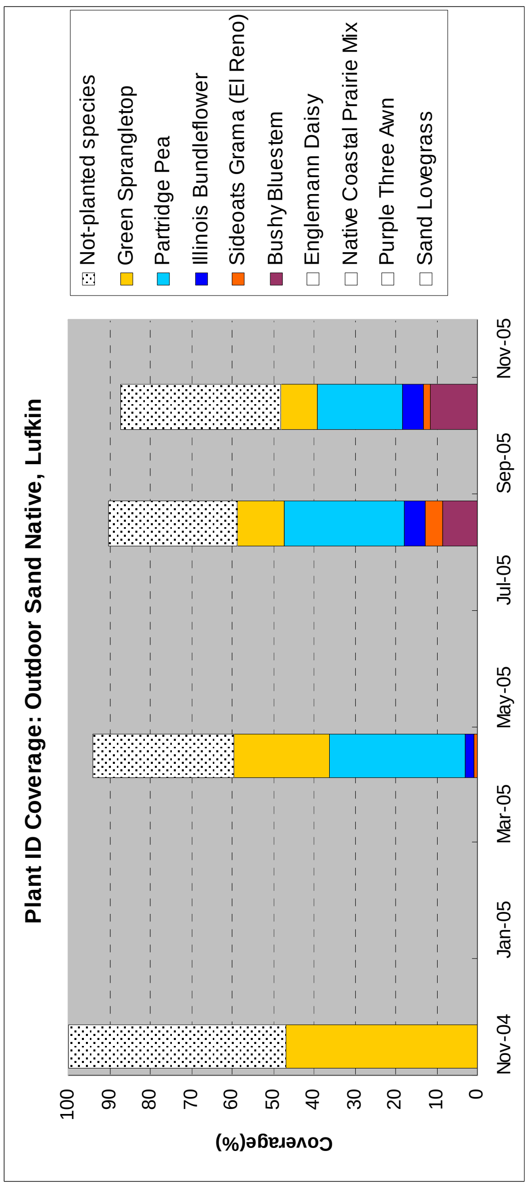
Lufkin Region

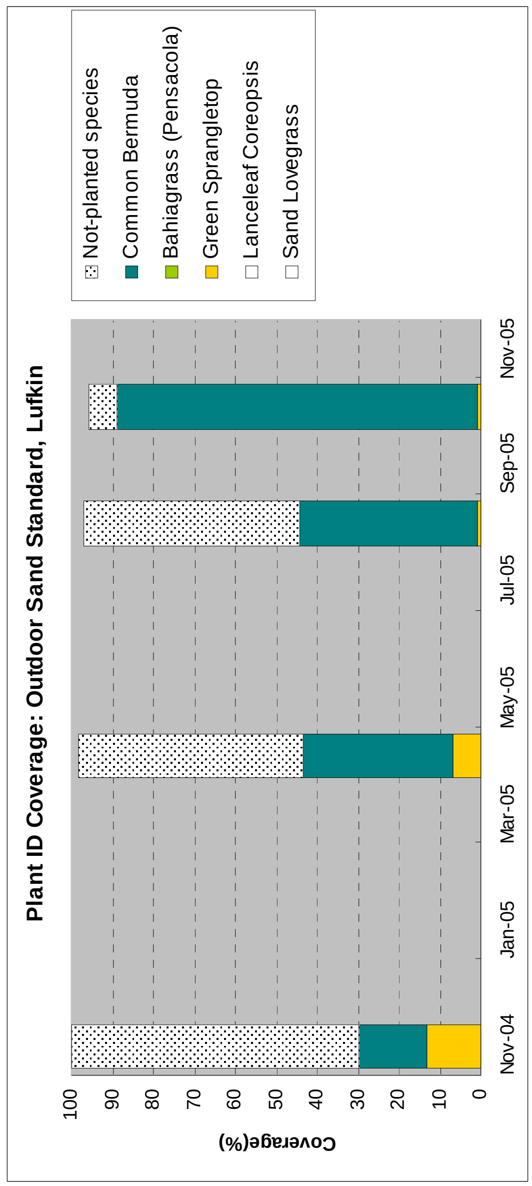
Outdoor Sand

Native	11/12/04	4/20/05	8/1/05	10/28/05
V-cap	100.00	94.15	90.36	87.12
Sand Lovegrass	0.00	0.00	0.00	0.00
Purple Three Awn	0.00	0.00	0.00	0.00
Native Coastal Prairie Mix	0.00	0.00	0.00	0.00
Englemann Daisy	0.00	0.00	0.00	0.00
Bushy Bluestem	0.00	0.00	8.33	11.67
Sideoats Grama (El Reno)	0.00	1.00	4.50	1.67
Illinois Bundleflower	0.00	2.00	5.00	5.00
Partridge Pea	0.00	33.33	29.33	20.67
Green Sprangletop	46.67	23.33	11.67	9.17
Not-planted species	53.33	34.48	31.52	38.95

Standard	11/12/04	4/20/05	8/1/05	10/28/05
V-cap	100.00	98.15	96.95	95.92
Sand Lovegrass	0.00	0.00	0.00	0.00
Lanceleaf Coreopsis	0.00	0.00	0.00	0.00
Green Sprangletop	13.33	6.67	1.00	0.67
Bahiagrass (Pensacola)	0.00	0.00	0.00	0.00
Common Bermuda	16.67	36.67	43.33	88.33
Not-planted species	70.00	54.82	52.62	6.92

* Non-native species: Common Bermuda, Bahiagrass


Plant ID Coverage: Outdoor Sand Native, Lufkin
Coverage(%)
0
10
20
30
40
50
60
70
80
90
100
Nov-04
Jan-05
Mar-05
May-05
Jul-05
Sep-05
Nov-05
Not-planted species
Green Sprangletop
Partridge Pea
Illinois Bundleflower
Sideoats Grama (El Reno)
Bushy Bluestem
Englemann Daisy
Native Coastal Prairie Mix
Purple Three Awn
Sand Lovegrass


Plant ID Coverage: Outdoor Sand Standard, Lufkin
Coverage(%)
0
10
20
30
40
50
60
70
80
90
100
Nov-04
Jan-05
Mar-05
May-05
Jul-05
Sep-05
Nov-05
Not-planted species
Common Bermuda
Bahiagrass (Pensacola)
Green Sprangletop
Lanceleaf Coreopsis
Sand Lovegrass

San Angelo Region

Outdoor Clay

District	2/9/06	6/6/06
V-cap	6.61	39.12
Buffalograss (Texoka)	0.00	0.00
Common Bermuda	0.00	2.33
Tall fescue	0.00	27.67
Not-planted species	6.61	9.12

* Non-native species: Common Bermuda, Tall fescue

Standard	2/9/06	6/6/06
V-cap	1.72	10.43
Sideoats Grama (Haskell)	0.00	0.00
Green Sprangletop	0.00	0.00
Buffalograss (Texoka)	0.00	1.67
Not-planted species	1.72	8.77

* All species are Native

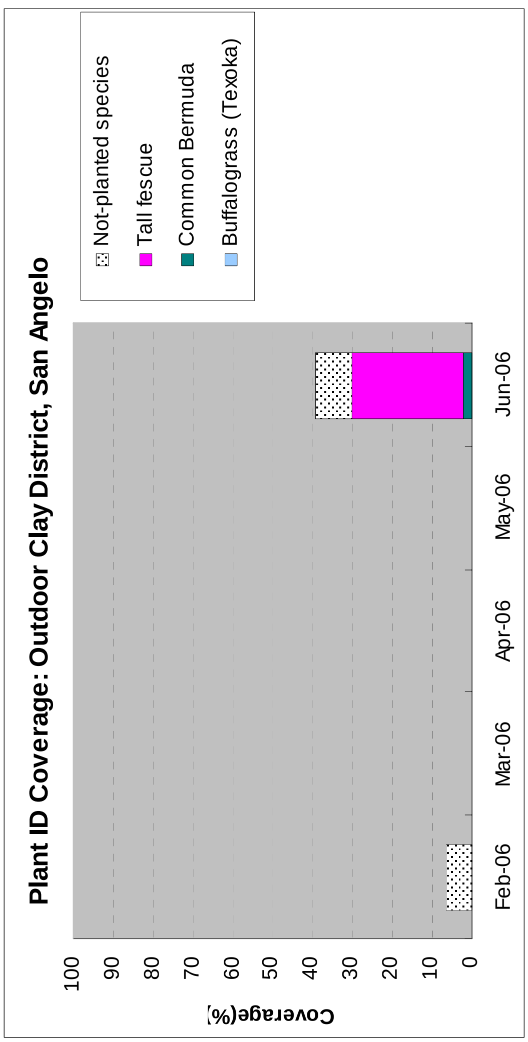
Inoor Clay

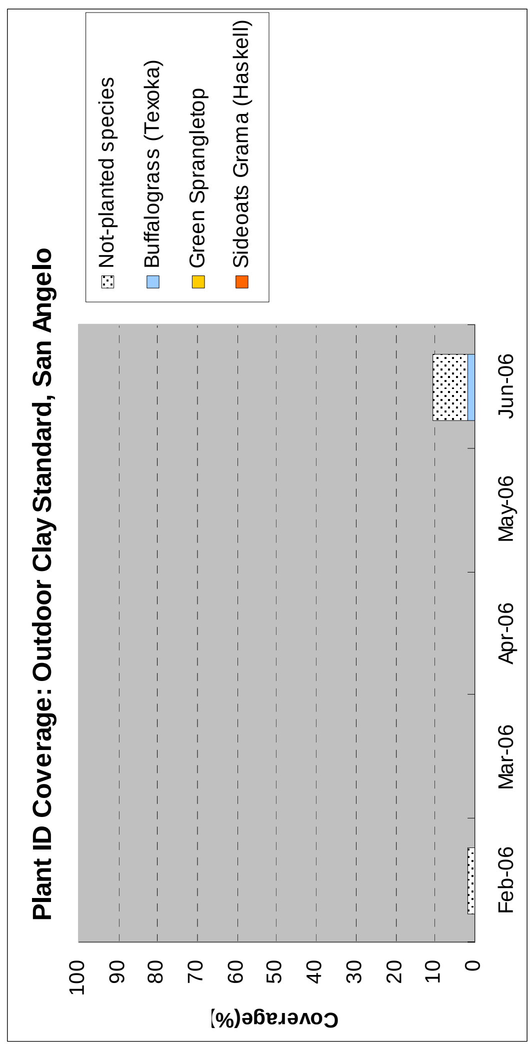
District	2/9/06	6/6/06
V-cap	47.80	69.05
Buffalograss (Texoka)	5.00	2.00
Common Bermuda	2.50	12.50
Tall fescue	40.00	50.00
Not-planted species	0.30	4.55

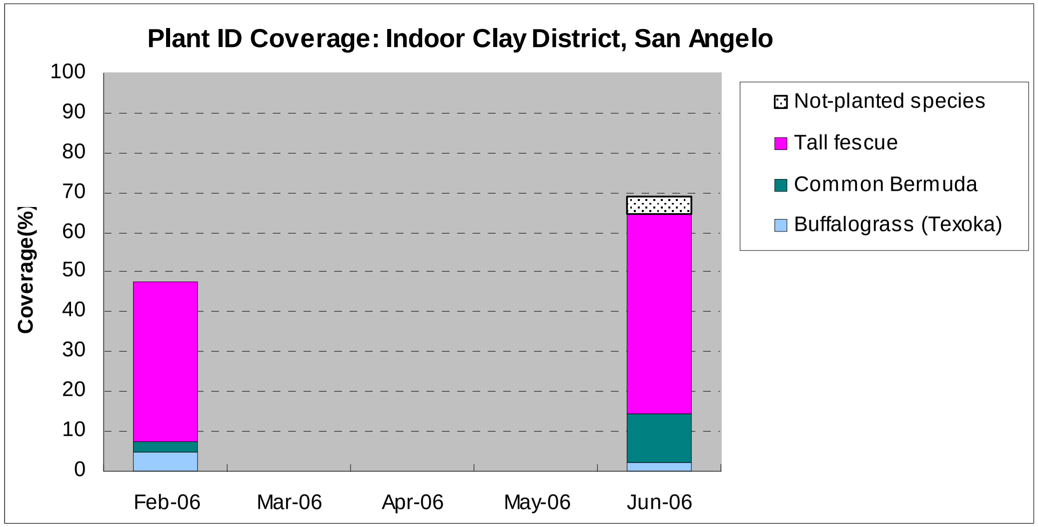
* Non-native species: Common Bermuda, Tall fescue

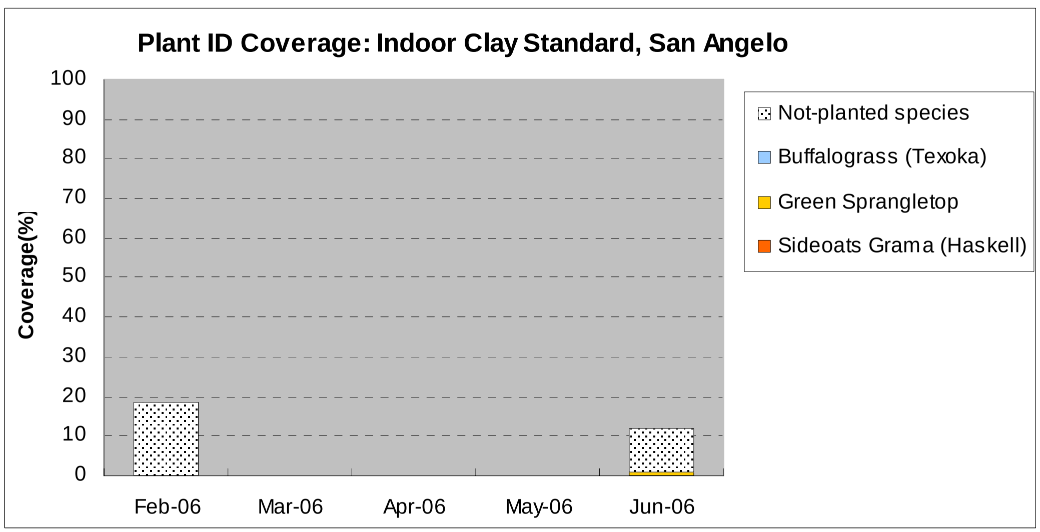
Standard	2/9/06	6/6/06
V-cap	18.53	11.93
Sideoats Grama (Haskell)	0.00	0.00
Green Sprangletop	0.00	1.00
Buffalograss (Texoka)	0.00	0.00
Not-planted species	18.53	10.93

* All species are Native


Plant ID Coverage: Outdoor Clay District, San Angelo
Coverage(%)
100
90
80
70
60
50
40
30
20
10
0
Feb-06
Mar-06
Apr-06
May-06
Jun-06
Not-planted species
Tall fescue
Common Bermuda
Buffalograss (Texoka)


Plant ID Coverage: Outdoor Clay Standard, San Angelo
Coverage(%)
100
90
80
70
60
50
40
30
20
10
0
Feb-06
Mar-06
Apr-06
May-06
Jun-06
Not-planted species
Buffalograss (Texoka)
Green Sprangletop
Sideoats Grama (Haskell)


Plant ID Coverage: Indoor Clay District, San Angelo
Coverage(%)
100
90
80
70
60
50
40
30
20
10
0
Feb-06
Mar-06
Apr-06
May-06
Jun-06
Not-planted species
Tall fescue
Common Bermuda
Buffalograss (Texoka)


Plant ID Coverage: Indoor Clay Standard, San Angelo
Coverage(%)
100
90
80
70
60
50
40
30
20
10
0
Feb-06
Mar-06
Apr-06
May-06
Jun-06
Not-planted species
Buffalograss (Texoka)
Green Sprangletop
Sideoats Grama (Haskell)

Lufkin Region (Cool Season)

Indoor Clay

Native	4/20/2005	6/24/2005
V-cap	92.50	97.25
Bottlebrush Squirreltail	0.00	0.00
Texas Wintergrass	0.00	0.00
Orchardgrass	85.63	90.00
Not-planted species	6.88	7.25

Standard	4/20/2005	6/24/2005
V-cap	92.50	75.50
Tall Fescue	2.75	0.00
Winter Wheat	4.63	0.00
Oats	71.63	60.00
Not-planted species	13.50	15.50

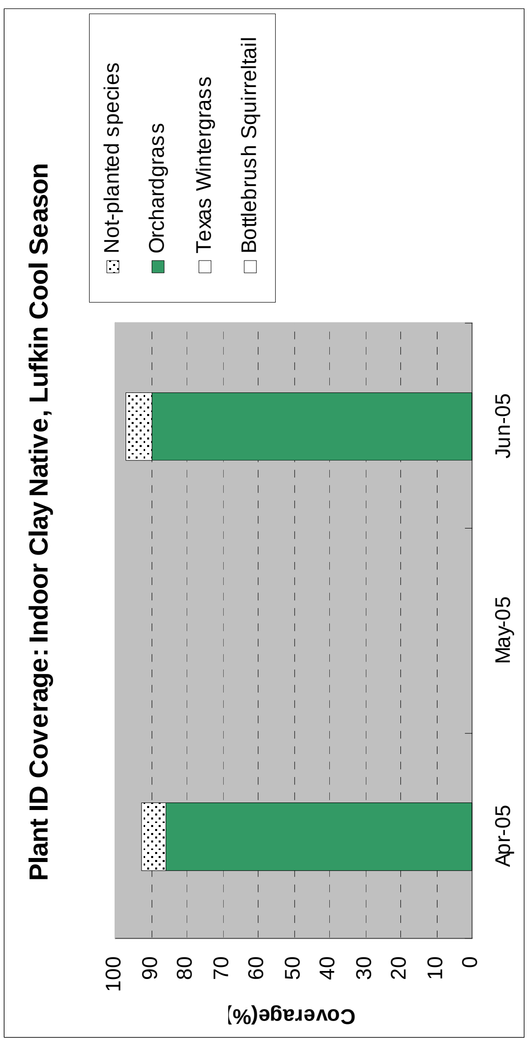
* All species are non-native

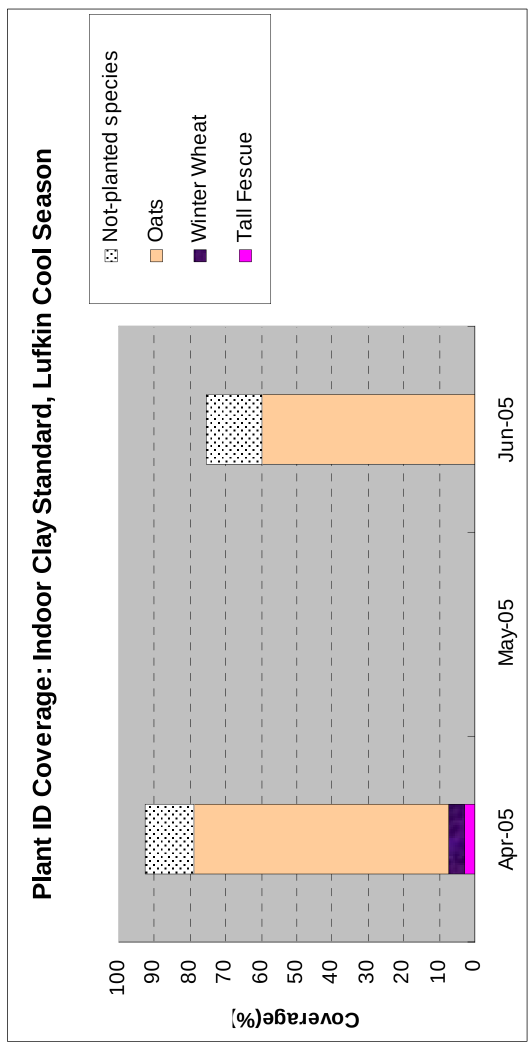
Indoor Sand

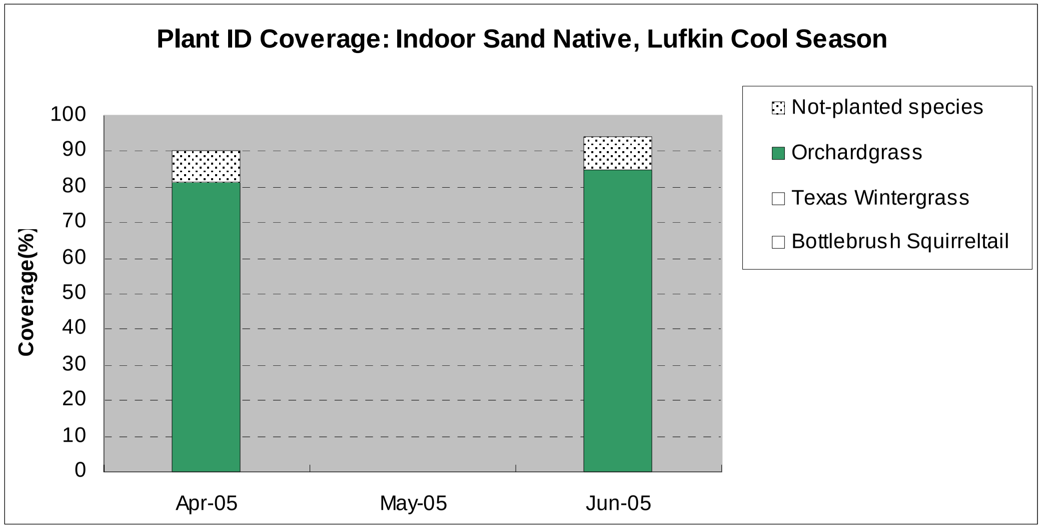
Native	4/20/2005	6/24/2005
V-cap	90.00	94.00
Bottlebrush Squirreltail	0.00	0.00
Texas Wintergrass	0.00	0.00
Orchardgrass	81.25	85.00
Not-planted species	8.75	9.00

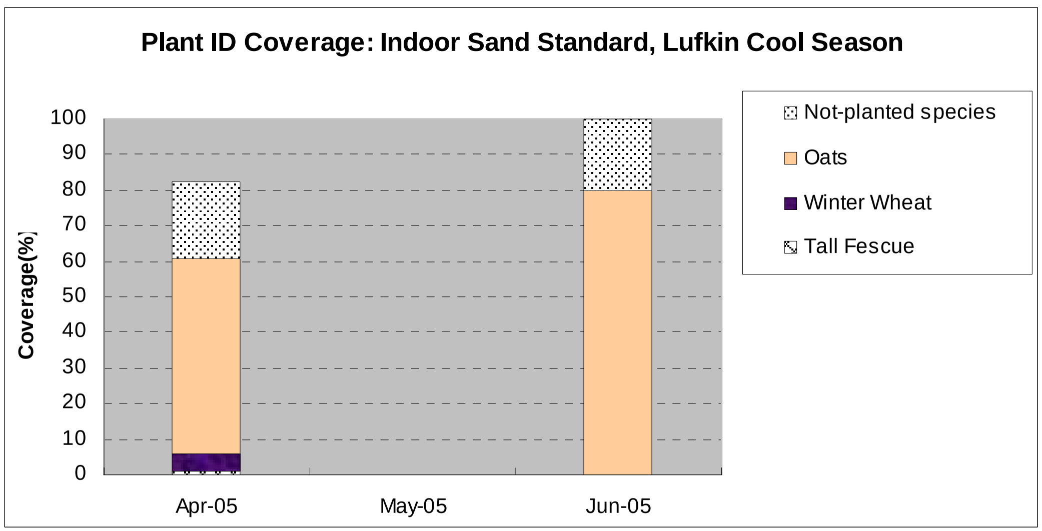
Standard	4/20/2005	6/24/2005
V-cap	82.50	100.00
Tall Fescue	0.75	0.00
Winter Wheat	5.10	0.00
Oats	54.75	80.00
Not-planted species	21.90	20.00

* All species are non-native


Plant ID Coverage: Indoor Clay Native, Lufkin Cool Season
Coverage(%)
100
90
80
70
60
50
40
30
20
10
0
Apr-05
May-05
Jun-05
Not-planted species
Orchardgrass
Texas Wintergrass
Bottlebrush Squirreltail


Plant ID Coverage: Indoor Clay Standard, Lufkin Cool Season
Coverage(%)
100
90
80
70
60
50
40
30
20
10
0
Apr-05
May-05
Jun-05
Not-planted species
Oats
Winter Wheat
Tall Fescue


Plant ID Coverage: Indoor Sand Native, Lufkin Cool Season
Coverage(%)
100
90
80
70
60
50
40
30
20
10
0
Apr-05
May-05
Jun-05
Not-planted species
Orchardgrass
Texas Wintergrass
Bottlebrush Squirreltail


Plant ID Coverage: Indoor Sand Standard, Lufkin Cool Season
Coverage(%)
100
90
80
70
60
50
40
30
20
10
0
Apr-05
May-05
Jun-05
Not-planted species
Oats
Winter Wheat
Tall Fescue

Appendix D
Water Analysis

Water Analysis Report 13-13-13 Fertilizer TX-DOT Rate Date 10-3-05

	2 hr	2.5 hr	3.5 hr	4 hr	Units	Drinking water limits	Livestock water limits	Irrigation water limits
Calcium (Ca)	40	22	17	22	ppm	Not Established	Recommend < 500 ppm	Not Established
Magnesium (Mg)	4	2	2	2	ppm	Not Established	Recommend < 125 ppm	Not Established
Sodium (Na)	173	195	202	198	ppm	20 ppm	Not Established	Reccommended <400 ppm
Potassium (K)	6	5	4	5	ppm	Not Established	Not Established	Not Established
Boron (B)	0.34	0.37	0.37	0.37	ppm	Not Established	5.0 ppm	1ppm (limiting) 2-10 OK
Carbonate (CO3)	0	0	0	0	ppm	Not Established	Not Established	<180 ppm
Bicarbonate (HCO3)	529	510	531	514	ppm	Not Established	Not Established	Not Established
Sulfate	12	6	6	9	ppm	250 ppm	2000 ppm	Not Established
Chloride	76	72	76	77	ppm	250 ppm	Not Established	900 ppm
Nitrate-N	0.23	0.3	0.24	0.19	ppm	**10 ppm***	< 100 ppm	< 40 ppm
Phosphorous (P)	0.85	0.87	0.85	1.26	ppm	Not Established	Not Established	Not Established
pH	7.7	8.1	8.4	8	·	6.5-8.5	5.5-8.5	Not Established
Conductivity	974	970	964	992	umhos/cm	Not Established	Not Established	Not Established
Hardness	7	4	3	4	grains CaCO3 /gallon	Not Established	Not Established	Not Established
Hardness	116	63	51	63	ppm CaCO3	Not Established	Not Established	Not Established
Alkalinity	434	418	435	421	ppm CaCO3	Not Established	< 500 ppm	Not Established
Total Dissolved Salts (TDS)	842	814	840	828	ppm	500 ppm	3000 ppm	Not Established
SAR	7	10.7	12.3	10.8	·	Not Established	Not Established	Not Established
Iron (Fe)	0.25	0.21	1.28	0.23	ppm	0.3 ppm	0.3 ppm	5 ppm
Zinc (Zn)	0.01	0.01	0.01	0.01	ppm	5.0 ppm	25 ppm	2.0 ppm
Copper (Cu)	0.01	0.01	0.01	0.01	ppm	**1.3 ppm***	0.5 ppm	0.2 ppm
Manganese (Mn)	0.09	0.01	0.02	0.01	ppm	0.05 ppm	0.1 ppm	0.2 ppm

*** Primary EPA Required Standard**

Non-Bold represents secondary EPA recommended standards

Water Analysis Report 23-0-3 Slow Release Nigrogen Tx-DOT Rate Date 11-11-05

	2 hr	2.5 hr	3.5 hr	4 hr	Units	Drinking water limits	Livestock water limits	Irrigation water limits
Calcium (Ca)	57	49	40	39	ppm	Not Established	Recommend < 500 ppm	Not Established
Magnesium (Mg)	8	7	5	6	ppm	Not Established	Recommend < 125 ppm	Not Established
Sodium (Na)	202	199	193	195	ppm	20 ppm	Not Established	Reccommended <400 ppm
Potassium (K)	28	26	21	21	ppm	Not Established	Not Established	Not Established
Boron (B)	0.35	0.36	0.39	0.38	ppm	Not Established	5.0 ppm	1ppm (limiting) 2-10 OK
Carbonate (CO3)	0	0	0	0	ppm	Not Established	Not Established	<180 ppm
Bicarbonate (HCO3)	482	496	505	503	ppm	Not Established	Not Established	Not Established
Sulfate	84	66	42	42	ppm	250 ppm	2000 ppm	Not Established
Chloride	111	103	88	85	ppm	250 ppm	Not Established	900 ppm
Nitrate-N	0.88	0.63	0.68	0.59	ppm	**10 ppm***	< 100 ppm	< 40 ppm
Phosphorous (P)	0.96	0.91	0.83	0.82	ppm	Not Established	Not Established	Not Established
pH	7.6	7.7	7.7	7.8	·	6.5-8.5	5.5-8.5	Not Established
Conductivity	1211	1154	1059	1055	umhos/cm	Not Established	Not Established	Not Established
Hardness	10	9	7	7	grains CaCO3 /gallon	Not Established	Not Established	Not Established
Hardness	175	151	120	122	ppm CaCO3	Not Established	Not Established	Not Established
Alkalinity	395	407	414	412	ppm CaCO3	Not Established	< 500 ppm	Not Established
Total Dissolved Salts (TDS)	974	948	896	893	ppm	500 ppm	3000 ppm	Not Established
SAR	6.6	7	7.6	7.7	·	Not Established	Not Established	Not Established
Iron (Fe)	1.23	1.21	1.03	1.74	ppm	0.3 ppm	0.3 ppm	5 ppm
Zinc (Zn)	0.05	0.02	0.01	0.01	ppm	5.0 ppm	25 ppm	2.0 ppm
Copper (Cu)	0.01	0.01	0.01	0.01	ppm	**1.3 ppm***	0.5 ppm	0.2 ppm
Manganese (Mn)	0.01	0.01	0.01	0.01	ppm	0.05 ppm	0.1 ppm	0.2 ppm
Arsenic (As)	0.01	0.01	0.01	0.017	ppm	**0.05 ppm***	0.2 ppm	0.10 ppm long term
Barium (Ba)	0.01	0.01	0.01	0.035	ppm	**2.0 ppm***	10 ppm	2.0 ppm
Nickel (Ni)	0.01	0.01	0.01	0.01	ppm	**0.1 ppm***	1.0 ppm	0.2 ppm long term
Cadium (Cd)	0.01	0.01	0.01	0.01	ppm	**0.05 ppm***	0.05 ppm	0.01 ppm long term
Lead (Pb)	0.01	0.01	0.01	0.01	ppm	**0.015 ppm***	0.10 ppm	5.0 ppm long term
Chromium (Cr)	0.01	0.01	0.01	0.01	ppm	**0.10 ppm***	1.00 ppm	0.1 ppm long term
Flouride (F)	1.37	1.32	1.28	1.33	ppm	**4.0 ppm***	2.0 ppm	1.0 ppm long term
Charge Balance	101	99	97	99		N/A	N/A	N/A

*** Primary EPA Required drinking water Standard**
Non-Bold represents secondary EPA recommended standards

Water Analysis Report   6-3-0 Houactinite & Houston Rate Compost   Date 11-23-05

	2 hr	2.5 hr	3.5 hr	4 hr	Units	Drinking water limits	Livestock water limits	Irrigation water limits
Calcium (Ca)	190	154	91	102	ppm	Not Established	Recommend < 500 ppm	Not Established
Magnesium (Mg)	33	31	19	20	ppm	Not Established	Recommend < 125 ppm	Not Established
Sodium (Na)	332	299	253	237	ppm	20 ppm	Not Established	Reccommended <400 ppm
Potassium (K)	181	194	126	116	ppm	Not Established	Not Established	Not Established
Boron (B)	0.81	0.82	0.77	0.65	ppm	Not Established	5.0 ppm	1ppm (limiting) 2-10 OK
Carbonate (CO3)	0	0	0	0	ppm	Not Established	Not Established	<180 ppm
Bicarbonate (HCO3)	657	654	612	572	ppm	Not Established	Not Established	Not Established
Sulfate	390	351	186	222	ppm	250 ppm	2000 ppm	Not Established
Chloride	524	467	298	298	ppm	250 ppm	Not Established	900 ppm
Nitrate-N	0.09	0.08	0.06	0.03	ppm	**10 ppm***	< 100 ppm	< 40 ppm
Phosphorous (P)	6.37	6.19	5	4.07	ppm	Not Established	Not Established	Not Established
pH	6.8	6.9	7	6.9	·	6.5-8.5	5.5-8.5	Not Established
Conductivity	3000	2810	1947	2030	umhos/cm	Not Established	Not Established	Not Established
Hardness	36	30	18	20	grains CaCO3 /gallon	Not Established	Not Established	Not Established
Hardness	610	512	305	337	ppm CaCO3	Not Established	Not Established	Not Established
Alkalinity	539	536	502	468	ppm CaCO3	Not Established	< 500 ppm	Not Established
Total Dissolved Salts (TDS)	2315	2157	1591	1571	ppm	500 ppm	3000 ppm	Not Established
SAR	5.8	5.7	6.3	5.6	·	Not Established	Not Established	Not Established
Iron (Fe)	0.12	0.37	0.89	1.82	ppm	0.3 ppm	0.3 ppm	5 ppm
Zinc (Zn)	0.05	0.02	0.01	0.02	ppm	5.0 ppm	25 ppm	2.0 ppm
Copper (Cu)	0.02	0.02	0.01	0.01	ppm	**1.3 ppm***	0.5 ppm	0.2 ppm
Manganese (Mn)	0.02	0.13	0.16	0.41	ppm	0.05 ppm	0.1 ppm	0.2 ppm
Arsenic (As)	N/A	N/A	N/A	N/A	ppm	**0.05 ppm***	0.2 ppm	0.10 ppm long term
Barium (Ba)	N/A	N/A	N/A	N/A	ppm	**2.0 ppm***	10 ppm	2.0 ppm
Nickel (Ni)	N/A	N/A	N/A	N/A	ppm	**0.1 ppm***	1.0 ppm	0.2 ppm long term
Cadium (Cd)	N/A	N/A	N/A	N/A	ppm	**0.05 ppm***	0.05 ppm	0.01 ppm long term
Lead (Pb)	N/A	N/A	N/A	N/A	ppm	**0.015 ppm***	0.10 ppm	5.0 ppm long term
Chromium (Cr)	N/A	N/A	N/A	N/A	ppm	**0.10 ppm***	1.00 ppm	0.1 ppm long term
Flouride (F)	N/A	N/A	N/A	N/A	ppm	**4.0 ppm***	2.0 ppm	1.0 ppm long term
Charge Balance	92	90	91	89		N/A	N/A	N/A

*** Primary EPA Required drinking water Standard**
Non-Bold represents secondary EPA recommended standards