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16. Abstract

The Texas Department of Transportation (TxDOT) has one of the largest right-of-way areas in the United States with over 127,138 km of state maintained highway. In 2003, the new guidelines for Texas Pollution Discharge Elimination System went into effect causing a renewed interest in TxDOT's strive to establish vegetation as quickly as possible. These guidelines, along with executive orders signed in 1999 and 2000, have brought about a growing interest in reducing spread and establishment of invasive non-native plant species, with emphasis on maintaining or increasing native species diversity and restoring ecosystem processes.

A two-year study was conducted in Andrews, Baylor, and Kleberg Counties in Texas. Our objectives were to test the hypotheses that 1) two native species, hooded windmillgrass (WMG) and shortspike WMG, provide similar vegetation canopy cover as the standard seed mixtures currently used by TxDOT when added as a component in a native seed mixture; 2) native WMGs would provide similar vegetative cover as bermudagrass with use of a soil retention blanket; 3) hooded and shortspike WMGs provide similar canopy cover as bermudagrass (*Cynodon dactylon)* on single species plots; and 4) drill planting technique would allow a greater proportion of seeds planted to establish a root system, therefore providing greater canopy cover when compared against a broadcasting technique.

17. Key Word Native Grasses, Right of Ways, hooded windmillgrass, *Chloris cucullata*, shortspike windmillgrass, *Chloris × subdolichostachya*, bermudagrass, *Cynodon dactylon*	18. Distribution Statement No restrictions. This document is available to the public through NTIS: National Technical Information Service Springfield, Virginia 22161 http://www.ntis.gov

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EVALUATION OF TEXAS NATIVE GRASSES FOR TXDOT RIGHT OF WAYS: TECHNICAL REPORT

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1. INTRODUCTION

An estimated 15-20% of the United States (US) land surface is ecologically affected directly by roads. These estimates reemphasized the immense scale and potential ecological impacts of roads (Forman and Alexander 1998). There has been a growing interest in the effects of transportation corridors on plant species composition (Angold 1997; Trombulak and Frissell 2000; Safford and Harrison 2001; Gelbard and Belnap 2003; Godefroid and Koedam 2004; Hansen and Clevenger 2005) with emphasis on establishment and spread of invasive, non-native plant species (Tyser and Worley 1992; Greenberg et al. 1997; Ullmann et al. 1998; Parendes and Jones 2000; Williamson and Harrison 2002; Hansen and Clevenger 2005). Roads in arid and semiarid landscapes of the American West have facilitated the ingress of exotic plants into natural areas (US, BLM 1999; Gelbard and Belnap 2003). With an estimated 40.5 million ha in the US that have already been infested (NISC 2001; Sheley and Krueger-Mangold 2003), invasive plant species have become an increasingly important conservation issue (di Castri 1990; Goodwin et al. 1999). Exotic grass invasions have cascading effects on ecosystems, causing simplification of plant, invertebrate, and ultimately vertebrate communities (Bock et al. 1986; Flanders et al. 2006), and these grasses invade an additional 14% of the terrestrial United States per year (Westbrooks 1998; Sheley and Krueger-Mangold 2003). With the intention of preventing the introduction of invasive species and controlling their spread, President Bill Clinton signed two Executive Orders (EO) on Invasive Species (EO 13112) (1999) and Greening the Government through leadership in Environmental Management (EO 13148) (2000). These orders focused on using existing programs to limit the introduction and spread of invasives while creating new programs to promote the use of native plant species (Clinton 1999, 2000; Venable 2005).

With over 127,138 km of state maintained highway, the Texas Department of Transportation (TxDOT) has one of the largest right-of-way areas in the nation (Jones et al. 2007). In 1990, the U.S. Environmental Protection Agency (EPA) developed the federal National Pollutant Discharge Elimination System (NPDES) storm water permitting program (EPA 2008). These new guidelines required TxDOT engineers to sign their names on Notices of Intent (NOI) and Notices of Termination (NOT) forms, holding engineers liable for damage caused by storm water run-off (TxDOT 2004). To reduce or eliminate storm water run-off, NPDES requires engineers to stabilize disturbed areas as quickly as possible (TxDOT 2004). In March 2003, the EPA authorized TxDOT to implement the NPDES storm water permitting program in the state of Texas with the Texas Commission on Environmental Quality (TCEQ) enforcing these new guidelines to obtain 70% perennial vegetative cover as quickly as possible, when compared to vegetation growing on adjacent property (TxDOT 2004).

Although native grasses are more desirable for highway right-of-way plantings, there are several reasons why exotic grasses are often preferred for use in revegetation projects. Introduced grasses tend to have more rapid rates of germination and growth and high seed production compared to native grasses. These characteristics are desirable where rapid vegetation recovery is needed to prevent soil erosion (Hunter and Omi 2006). Previous and current hesitancy to use native seeds for large-scale rehabilitation projects is associated with increased cost, lack of seed availability (Roundy et al. 1997), and the perception that natives do not establish or compete as well as introduced species on lands at risk of rapid weed invasion (Thompson et al. 2006) (Table A-1). Due to their known ability to control erosion, ease of establishment, and cost-effectiveness, nearly all species used for erosion control are non-native and/or invasive (Skousen and Fortney 2003; Venable 2005). However, these same characteristics may allow introduced species to out-compete native species and prevent natural recovery of these areas (Hunter and Omi 2006).

Numerous studies have shown that native and exotic grasses respond differently to available resources such as water, nitrogen, and light due to their differing evolutionary histories (Melgoza et al. 1990; Naumburg and DeWald 1999; Abbot and Roundy 2003; Brooks 2003; Hunter and Omi 2006). Exotic grasses effectively compete with native species for soil nutrients. For example, nitrate disappeared more rapidly from soil in plots planted with an exotic grass than in plots with native grasses (Elliott and White 1989; D'Antonio and Vitousek 1992). This strategy difference in resource utilization can ultimately allow one species to competitively exclude another (Brooks 2000; Corbin and D'Antonio 2004; Humphrey and Schupp 2004; Hunter and Omi 2006). There is evidence, though, that some native species may establish and compete as well as some introduced species (Pyke et al 2003; Huber-Sannwald and Pyke 2005; Thompson et al. 2006). Waldron et al. (2005) noted in their study that natives may have limited establishment when sown with more competitive introduced species that have high initial establishment, such as crested wheatgrass (*Agropyron cristatum* (L.) Gaertn. ssp. *Cristatum)*, but establish better when sown with less readily established species such as Russian wildrye (*Psathyrostachys juncea* (Fisch.) Nevski) (Thompson et al. 2006).

Interest in using native species has evolved from a number of different practical and environmental concerns, such as the need to use regionally native seeds to achieve greater survivability, and concerns over the escape of introduced species (Landphair et al. 2001). During the past 50 years, the comparatively high success of exotic grasses generally resulted in a lack of research, development, and use of native plant materials (Roundy et al. 1997). Native plant seeds have particularly been difficult to obtain in the past for planting in south Texas because the majority of the seeds available are from ecotypes that are adapted to central or northern Texas (Fulbright et al. 1998). Concern about the negative impacts of planting exotic species has prompted greater emphasis on use of native plants in roadside planting in the US (Fulbright et al. 1998). To address this issue, the USDA, NRCS, "Kika" de la Garza Plant Materials Center along with South Texas Natives at Texas A&M University-Kingsville are developing native grasses such as hooded windmillgrass (WMG) (*Chloris cucullata* Bisch.) (Fig. 1-1) and shortspike WMG (*Chloris ×subdolichostachya* Müll. Berol. (pro sp.) [*cucullata* × *verticillata*]) (Fig. 1-2), to serve as competitors to exotic, introduced plant species.

Figure 1-1. Hooded windmillgrass seedheads and seeds.

Figure 1-2. Shortspike windmillgrass seedheads and seeds.

Hooded and shortspike WMGs are warm season perennial grasses (Gould 1975; Hatch et al. 1999; Herrera-Cedano et al. 2006) native throughout Texas, Oklahoma, New Mexico (Hitchcock 1971; Herrera-Cedano et al. 2006), and northeastern Mexico (Gould 1975; Herrera-Cedano et al. 2006). They can be found in prairies on sandy or gravelly soils, and occasionally on clayey soils (Correll and Johnston 1996; Herrera-Cedano et al. 2006). In Texas, hooded and shortspike WMGs are more abundant in the Rio Grande Plains, although they can be found throughout most of the state (USDA, NRCS 2005; Herrera-Cedano et al. 2006). Native windmillgrasses evolved in the harsh environments of Texas, which demonstrates their potential for long-term sustainability along right of ways. These native grasses can reach full height within six months, germinate quickly, and succeed in south Texas temperatures with minimal resource input. It is these attributes that make both native grasses good candidates for planting on highly erodible sites and on sites where introduced species are not desired (Herrera-Cedano et al. 2006). The following species were used in all experiments: hooded WMG accession numbers 9085301 or 9085313, shortspike WMG accession numbers 9085260 or 9085283. There is growing evidence that native species are capable of outperforming their exotic counterparts both in aesthetic and establishment attributes (Simmons et al. 2007).

2. LITERATURE REVIEW

2.1 Revegetating Texas Roadsides with Native Seed Mixtures

Recent literature reviews on the ecological effects of roads (Spellerberg 1998; Trombulak and Frissell 2000; Fowler et al. 2008) have focused on biotic and physical impacts of roads worldwide with particular emphasis on roadside soils and exotic plant species (Fowler et al. 2008). One of the primary reasons for establishing vegetation cover is to protect the surface from erosion (Landphair et al. 2001). Because of their quick establishment, dependability, and vigor, exotic grasses are often used in revegetation projects (Round et al. 1997) and have been intentionally introduced through seed mixtures planted along roadsides to address this very issue (Tyser and Worley 1992; Parendes and Jones 2000; Fowler et al. 2008).

Native plants are important from a conservation point of view, as they can maintain natural plant diversity (Knops et al. 1995; Karim and Mallik 2008). Texas Department of Transportation's (TxDOT) permanent rural seed mixtures for roadsides have recently been updated to include more native species and a few legumes, but still a few introduced species. These seed mixes are derived from diverse criteria that include: 1) the Natural Resources Conservation Service's (NRCS) "critical area" seeding list that refers to species the NRCS has documented to occur most commonly in a particular geographic area, 2) species are selected based upon their ability to control erosion and to withstand 18 cm mowing height specifications, 3) TxDOT plants shorter species in urban areas and taller species in rural areas. These urban and rural categories are broken into species that perform better in sandy soils and those that perform better in clay soils; and 4) given the amount of hectares that are planted in Texas, commercial availability of a species is also an important factor (TxDOT 2004).

Restoring highly disturbed ecosystems to a highly diverse natural area is difficult (Link 2007). Because of the level of difficulty during revegetation projects, exotic grasses are often used. Furthermore, they are available in large quantities, are relatively inexpensive, and at times have growth characteristics that allow them to germinate and establish quickly relative to native species that would naturally recover at that site (Richards et al. 1998; Robichaud et al. 2000; Hunter and Omi 2006). Based on early efforts using common native grass species, it was believed that native grasses could not be used for rapid revegetation. Landphair et al. (2001) found from their research that native species do require an extended period of time to develop, but as they develop, it appears that erosion control properties are at least equal to the introduced species currently in use by TxDOT. However, a recent roadside study conducted by Tinsley et al. (2006), demonstrated that after 60 days from sowing, the seedling densities of two purely native mixes were up to five times greater than the recommended non-native seed mixture (Simmons et al. 2007). Additional studies have shown that mixed seedings of exotics and natives often resulted in exotic monocultures that supported little diversity (Pyke 1996; Roundy et al. 1997).

Roundy et al. (1997) noted from their study that seeding rates, particular species and sites, and initial seedling establishment determine whether or not seeding mixtures of exotic and native species will eventually become dominated by exotics. This trend was previously demonstrated by Harris and Dobrowolski (1986) with their trials in northeastern Washington using hard fescue (*Festuca ovina* var. *duriuscula*). The species was so aggressive, that after 30 years it had displaced many of the other species seeded in adjacent plots (Roundy et al. 1997). More recently, Landphair et al. (2001) found through their research that the introduced species bermudagrass (*Cynodon dactylon* (L.) Pers.) invaded and became fairly abundant in plots were it was not originally planted.

The objective of this study was to compare a mixture of native seeds, including hooded WMG and shortspike WMG, to the standard seed mixture currently used by TxDOT, which includes a combination of introduced and native grasses, in different soils and ecoregions throughout Texas. The aim of this experiment was to obtain similar vegetation cover using an all native seed mix to achieve 70% canopy cover as quickly as possible to meet EPA's final soil stabilization requirements, as the standard seed mixture currently used by TxDOT.

2.2 Establishing Roadside Vegetation with Soil Retention Blankets

Invasive species enter various habitats (Baker 1986; Fox and Adamson 1986; Gray 1986; Mooney et al. 1986; Mack 1989; Goodwin et al. 1999) and may alter ecosystem properties and processes (Vitousek 1986; Le Maitre et al. 1996; Goodwin et al. 1999) and native plant community structure (Simberloff 1981; Goodwin et al. 1999). Once established at roadsides, alien species may spread along these corridors due to traffic, wind, water or animals, contributing to homogenize the roadside communities (Clifford 1959; Greenberg et al. 1997; Arévalo 2005). Replacement of native species and dominance by alien grasses may also result from demographic differences between native and alien species (D'Antonio and Vitousek 1992); higher seed output, lower seed predation, and the buildup of a large seedbank (Pyke 1990; D'Antonio and Vitousek 1992). The superior stand-establishment characteristics, hardiness, wide adaptability, availability and lower cost of seed, and productivity of introduced perennial species compared with indigenous native species have been documented in many regions (Barker et al. 1977; Kilcher and Looman 1983; Lawrence and Ratzlaff 1989; Asay et al. 2001). These advantages have led to continued use of introduced grasses on federal lands, even though government policy suggests otherwise (Richards et al. 1997; Asay et al. 2001).

Plant colonization is a key issue in the restoration of road embankments because it is widely accepted that vegetation has a role in controlling soil loss and runoff (Snelder and Bryan 1995; Andrés and Jorba 2000; Tormo et al. 2006). To encourage plant colonization, soil stabilization materials, specifically soil retention blankets (SRBs) should be used for several reasons: aid in slowing evaporative water loss from soil; minimize wind redistribution of seed and fine soil particles; moderate soil surface temperature extremes; minimize chances of erosion; and maximize seed trapping of native species from surrounding plant communities (Brown and Amacher 1999). TxDOT bases material selection for SRBs on an Approved Product List (APL), to maintain federal regulatory compliance and ensure that the most effective erosion control products are used on its maintenance and construction projects (McFalls et al. 2007). These products that have been approved for erosion control in Texas are listed in TxDOT's 2004 manual, *A Guide to Roadside Vegetation Establishment*. The Texas Department of Transportation considers SRBs to be the best soil stabilizing devices and encourages their use where soil erosion could be a problem (TxDOT 2004).

The following erosion control criteria are required by TxDOT on plots covered by an approved SRB: soil retention blankets should effectively protect the seed bed from a short duration and one-year return frequency within the first month after installation; and promote significantly greater vegetation cover on the protected treatment area compared to bare ground within the first six months after installation (McFalls and Landphair 1996; Landphair et al. 2001). Brown and Amacher (1999) also strongly favor SRBs, especially constructed with natural biodegradable netting, due to their ease of application and efficiency in achieving the goals of surface mulching. It is encouraging to note that increasingly, restoration efforts are motivated not only by efforts to conserve biodiversity, but also to provide ecosystem services, such as erosion control and water purification (Holl and Howarth 2000; Aronson et al. 2007; Rein et al. 2007).

Grasses along highway rights of way live in a harsh environment because of the time, frequency, and height of annual mowing. Roadside mowings tend to both reduce plant species richness and favor exotic plants (Ross 1986; Panetta and Hopkins 1991; Forman and Alexander 1998). Consequently, many native, late-seral grasses are absent from the rights of way (Nofal et al. 2004). Mowing roadsides favors exotic plant species that are less sensitive to clipping than native flora (Forman and Alexander 1998; Benefield et al. 1999; Gelbard and Belnap 2003). In Australia, a positive correlation between disturbance and invasion by exotic plants is widely recognized (Groves and Burdon 1986; McIntyre and Lavorel 1994). Seabloom et al. (2003) noted in their study that the abundance of exotic species increased with increasing levels of disturbance. Dewey et al. (2006) found in their research that mowing decreased species diversity, and diversity was best maintained under non-mowed conditions. Landphair et al. (2001) also noted in their study that in the absence of mowing, particularly at common roadside heights of 10 to 15 cm, native grass species continued development. It has become common practice to keep roadsides mowed continually, with consequences ranging from high maintenance costs, monocultures of grassy vegetation, to “front lawn” expectations from the traveling public (Harper-Lore and Wilson 1999).

The objectives of this study were to 1) compare canopy cover of seeding treatments with and without the use of a soil retention blanket, 2) compare the establishment of four accessions of windmillgrasses and bermudagrass in monoculture plots, and 3) evaluate impacts of mowing on established plots of native hooded and shortspike WMGs. We predicted that use of SRBs would promote a rapid, dense growth of warm-season, perennial vegetative cover required by TxDOT’s standards. Native windmillgrasses evolved in the harsh environments of Texas, which demonstrates their potential for long-term sustainability along rights of way. Hooded and shortspike windmillgrasses possess important reproductive characteristics, such as rapid germination, strongly stoloniferous growth habit, and production of seeds throughout the year.

2.3 Native Alternatives to Introduced Species

Restoration and revegetation projects are frequently undertaken after construction or other anthropogenic activities have severely disturbed a site (Montalvo et al. 2002). Lack of data supporting the use of native species on large-scale projects contributes to their limited use on federal lands. Studies comparing native to introduced species have commonly used single-species comparisons on small-scale research plots (Thompson et al. 2006). Such studies have often highlighted the limitations of native species establishment on semiarid rangelands compared to introduced species (Asay et al. 2001; Thompson et al. 2006). Introducing and establishing desirable competitive plants is essential for successful management of invasive plants and the reestablishment of desirable plant communities (Bottoms and Whitson 1998; Laufenberg 2003; Sheley and Carpinelli 2005).

The goals of revegetation on these sites may vary, but there is usually a demand for rapid establishment of a plant community to control erosion and prevent further loss of topsoil (Montalvo et al. 2002). The current method is to provide a vegetation cover that is fast-growing and easy-to-establish (Venable 2005). However, owing to their known ability to control erosion, ease of establishment, and cost-effectiveness, nearly all species used for this control are non-native and/or invasive (Skousen and Fortney 2003; Venable 2005). Montalvo et al. (2002) noted in their study that many factors may influence initial plant establishment, including the choice of plant species, origin of seed sources, planting methods, seedbed preparation, and natural variation in the soil. Grasses with characteristics such as rapid rates of germination and growth and high seed production may be desirable for use in rehabilitation treatments where rapid vegetation recovery is needed to prevent soil erosion. However, these same characteristics may allow them to outcompete native species and prevent natural recovery of these areas (Hunter and Omi 2006). Exotic grasses are often used because they are available in large quantities, are relatively inexpensive, and at times have growth characteristics that allow them to germinate and establish quickly relative to native species that would naturally recover from that area (Richards et al. 1998; Robichaud et al. 2000; Hunter and Omi 2006). Although rapid development of grass cover fulfills the objective of road engineers by controlling soil erosion and slope stabilization, other ecological and conservation requirements are not met by this method (Karim and Mallik 2008).

Roadsides, normally being open, well-lighted and regularly mown areas, are potential habitats for grassland species adapted to continuous disturbance (Tikka et al. 2001). In Australia, a positive correlation between disturbance and invasion by exotic plants is widely recognized (Groves and Burdon 1986; McIntyre and Lavorel 1994). Landphair et al. (2001) reported that in the absence of mowing, particularly at common roadside heights of 10 to 15 cm, native grass species continued development. Seabloom et al. (2003) noted in their study that the abundance of exotic species increased with increasing levels of disturbance. More recently, Dewey et al. (2006) found in their research that mowing decreased species diversity and was best maintained under non-mowed conditions. Non-native species, including those planted during construction for sediment and erosion control, and those that become established after construction, often occurred at greater frequency and abundance than native species (Rentch et al. 2005). With disturbance comes invasive species; to preserve natural diversity, it is necessary to maintain the full complement of native plant species in a natural area (Link 2007).

Native windmillgrasses evolved in the harsh environments of Texas, which demonstrates their potential for long-term sustainability along right of ways. Hooded and shortspike windmillgrasses possess important reproductive characteristics, such as rapid germination, strongly stoloniferous growth habit, and production of seeds throughout the year. The objectives of this study were: 1) compare the establishment of four accessions of native WMGs (hooded WMG: 9085301 and 9085313, and shortspike WMG: 9085260 and 9085283) with the establishment of bermudagrass in monoculture plots, and 2) evaluate impacts of mowing on established plots of native hooded and shortspike WMGs. We hypothesized that 1) native windmillgrasses would be able to provide the same percent canopy cover when compared against bermudagrass, and 2) native WMGs will adapt to the regular maintenance mowing regimens conducted by TxDOT and provide sustainable long-term results along Texas rights of way.

2.4 Assessment of Two Commonly Used Seeding Techniques

The primary objectives of roadside restoration are to mitigate road effects by controlling soil erosion, exotic plant invasion, and maintaining traffic visibility (Karim and Mallik 2008). Naturally occurring roadside native plants have high potential to survive and regenerate in disturbed habitats (Prach and Pysek 2001; Karim and Mallik 2008). Forman and Alexander (1998) reported in their research that the establishment of self-sustained native vegetation cover in newly constructed roadside habitats may reduce invasion of exotic species and soil erosion (Karim and Mallik 2008).

Commonly used seeding methods include: hydroseeding, dry broadcasting with imprinting, drilling, and dry broadcasting (Dixon 1990; Munshower 1994; Montalvo et al. 2002). According to TxDOT (2004), seeding is the primary method of establishing vegetation on roadside rights of way. There are two common techniques suggested by TxDOT for revegetating roadsides: broadcast seeding and drill seeding. Broadcast seeding is the process of scattering seeds out on a prepared seedbed, while drill seeding buries seeds in the soil. A common problem with broadcasting is that a certain percentage of seeds never establish root systems. Drilling on the other hand, allows a greater proportion of seeds planted to establish a root system because it places them directly in the soil (TxDOT 2004).

Not all seeding methods are appropriate for all environments and combinations of species. Montalvo et al. (2002) stated from their research that flat-to-gently sloping areas can utilize any of these methods, but with varying success. To enable germination, seeds of some species must be buried and others must be at or near the soil surface. Dry broadcasting can be problematic because seeds are completely exposed to erosion and seed foragers, resulting in loss of many seeds (Montalvo et al. 2002). Published research comparing planting methods for native seed mixtures is sparse (Stromberg and Kephart 1996), and research that experimentally compares hydroseeding, imprinting, and drilling using a standardized mixture of native seeds is lacking (Montalvo et al. 2002).

Young (1992) noted that inappropriate seedbed preparation or sowing techniques resulted in some native species failing to establish in the past (Roundy et al. 1997). When small-seeded species are drilled too deep, establishment of these species decreases. Broadcasting small-seeded species into seedbeds roughened through mechanical treatments resulted in increased establishment (McArthur et al. 1995; Roundy et al. 1997). While drill seeding was the most consistently successful planting technique in Cox and Anderson's (2004) research, they did note that it can be impractical at times and is limited by area. With this in mind, broadcasting may be as effective as drilling in certain conditions, especially when the seed is covered (Winkel et al. 1991; Roundy et al. 1993; Cox and Anderson 2004).

The objective of this study was to compare the percent canopy cover obtained from plots that were drilled seeded versus hand broadcasting within 90 days of planting. We predicted that the drill seeding technique would allow a greater proportion of seeds planted to establish a root system, therefore providing greater canopy cover. Broadcasting, on the other hand, would provide a lower percentage of canopy cover due to a certain percentage of seeds never establishing root systems.

3. METHODS

3.1 Study Areas

Research was conducted in three different ecoregions in Texas: 1) the High Plains ecoregion in Andrews County (lat 32º08'24"N, long 102º28'05"W), 2) the Rolling Plains ecoregion in Baylor County (lat 33º36'52.84"N, long 99º15"38.42"W on sandy soil; lat 33º30'06.91"N, long 99º26'30.32"W on clay soil), and 3) the South Texas Plains ecoregion in Kleberg County (lat 27º33'07.60"N, long 97º52'41.81"W on sandy soil; lat 27º32'58.60"N, long 97º52'42.26"W on clay soil) (Fig. 3-1).

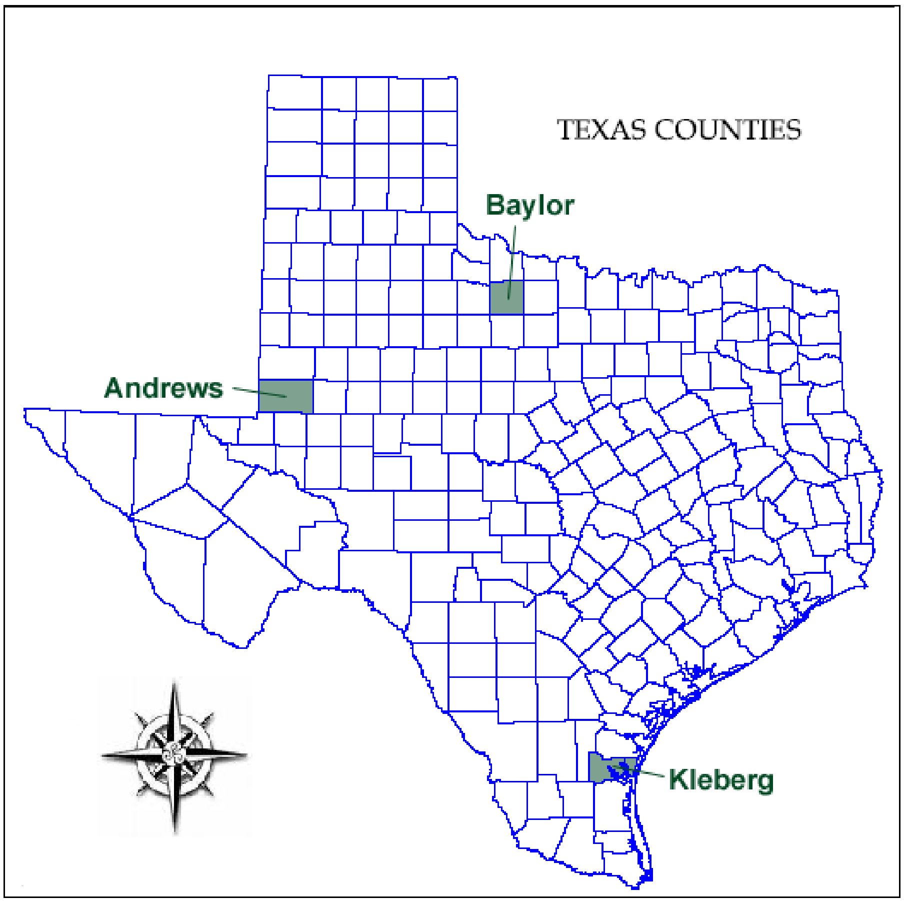

Figure 3-1. Map of Texas indicating the three counties where the study sites were located.

3.1.1 Andrews County

Andrews County is in the southern High Plains of Texas and covers over 389,534 ha. The county consists of rolling prairieland with the elevation ranging from 914 to 1036 m (Handbook of Texas Online 2008). The dominant soil order for this county is Aridisol (Soil Survey Staff, NRCS 2006), with the Faskin-Douro soil association of fine sandy loams dominating the study site (Fig. 3-2). This association is deep to moderately deep with moderately permeable fine sandy loams nearly level to gently undulating soils on uplands.

Faskin soils make up about 70% of the association with fine-loamy, siliceous, superactive, thermic Ustic Calciargids (USDA-NRCS 2001) about 20.3 cm thick (USDA-NRCS 1974); Douro soils make up approximately 25% of the association with fine-loamy, siliceous, active, thermic Ustalfic Petrocalcids (USDA-NRCS 2000) about 22.9 cm thick (USDA-NRCS 1974). The remaining 5% consists mainly of Blakeney, Conger, Lipan, Ratliff, Slaughter, Stegall, and Wickett soils (USDA-NRCS 1974).

Figure 3-2. Study site in Andrews County, Texas, on sandy soil.

Andrews County has mild winters with a cool-temperate, dry steppe climate (USDA-NRCS 1974). The mean annual temperature is 35.6 ºC (Handbook of Texas Online 2008) with an average annual (1971-2000) rainfall of 26.90 mm (Fig. 3-3) (NOAA 2008b). Approximately 84% of this amount falls during April through October (USDA-NRCS 1974). Characteristic grasses on these sandy loam soils are little bluestem (*Schizachyrium scoparium* (Michx.) Nash), western wheatgrass (*Pascopyrum smithii* (Rydb.) A. Löve), sideoats grama (*Bouteloua curtipendula* (Michx.) Torr.), and sand dropseed (*Sporobolus cryptandrus* (Torr.) A. Gray) (Hatch and Pluhar 1993). The prevailing winds in this area are southwesterly from November through March and southeasterly to south-southeasterly from May through September. The average annual wind speed is about 16.74 km/h (USDA-NRCS 1974). Erosion control can be challenging for this area with high winds, dry winters, and low annual rainfall (Hatch and Pluhar 1993).

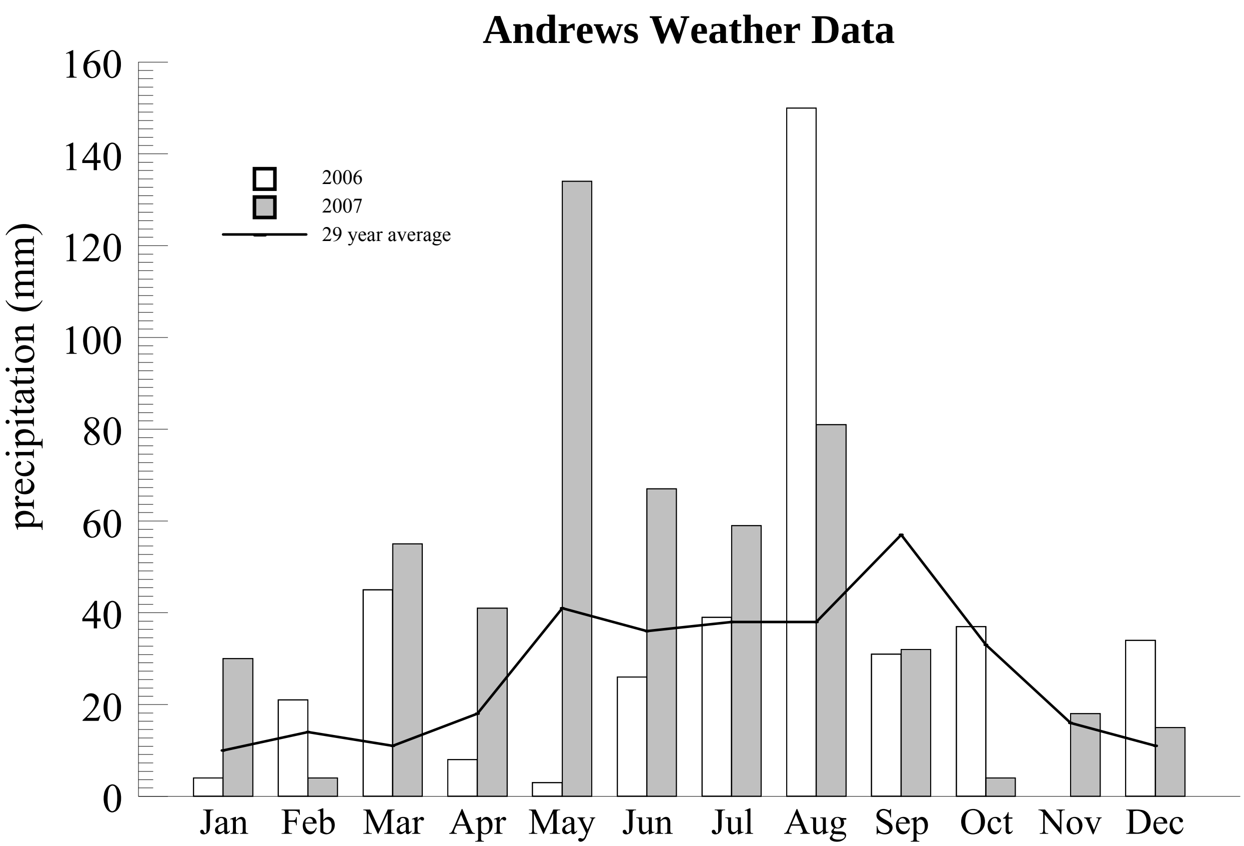

Figure 3-3. Monthly (2006-2007) and monthly average (1971-2000) precipitation in millimeters (mm) at Midland, Texas, Midland International Airport weather station, located about 33 km from the study site.

3.1.2 Baylor County

Baylor County is in the Rolling Plains ecoregion of Texas and covers over 218,853 ha (Handbook of Texas Online 2008). The county consists of deep, nearly level to gently sloping soils on uplands with elevation ranging from 320 to 914 m. The dominant soil order for this county is Mollisol (Soil Survey Staff, NRCS 2006), with the Miles soil series dominating the sandy soil study site by making up approximately 99% of the soil with the remaining 1% consisting of Enterprise and Hardeman soils (Fig. 3-4). The soils have a surface layer of brown fine-loamy, mixed, superactive, thermic Typic Paleustalfs (USDA-NRCS 2002) about 35.6 cm thick and underlain by reddish-brown, very friable sandy clay loam about 15.2 cm thick (Soil Survey Staff, NRCS 2008). The clay soil study site is dominated by Tillman clay loam, fine, mixed, superactive, thermic Vertic Paleustolls (USDA-NRCS 1999), with elevation ranging from 304 to 686 m (Soil Survey Staff, NRCS 2008) (Fig. 3-5). Tillman soils make up 100% of the study site and are formed in Permian red-bed clay and shale. The soils have a surface layer of reddish-brown, firm clay loam about 17.8 cm thick and underlain by reddish-brown, very firm clay about 28 cm thick (Soil Survey Staff, NRCS 2008).

Figure 3-4. Study site in Baylor County, Texas, on sandy soil.

Figure 3-5. Study site in Baylor County, Texas, on clay soil.

Baylor county has a mean annual temperature of 36.7 ºC (Handbook of Texas Online 2008) with an average annual (1971-2000) rainfall of 59.37 mm (NOAA 2008a) (Fig. 3-6). The original vegetation included tall and mid-grasses such as little bluestem, big bluestem (*Andropogon gerardii* Vitman), sand bluestem (*Andropogon hallii* Hack.), sideoats grama, indiangrass (*Sorghastrum nutans* (L.) Nash), switchgrass (*Panicum virgatum* L.), hairy grama

(*Bouteloua hirsuta* Lag.), blue grama (*Bouteloua gracilis* (Willd. ex Kunth) Lag. ex Griffiths), Canada wildrye (*Elymus canadensis* L.), and western wheatgrass on the moister sites. Buffalograss (*Bouteloua dactyloides* (Nutt.) J.T. Columbus), common curlymesquite (*Hilaria belangeri* (Steud.) Nash), tobosa (*Pleuraphis mutica* Buckley), threeawns (*Aristida* L.), sand dropseed, and hooded windmillgrass are more common on the more xeric or overgrazed areas (Hatch and Pluhar 1993).

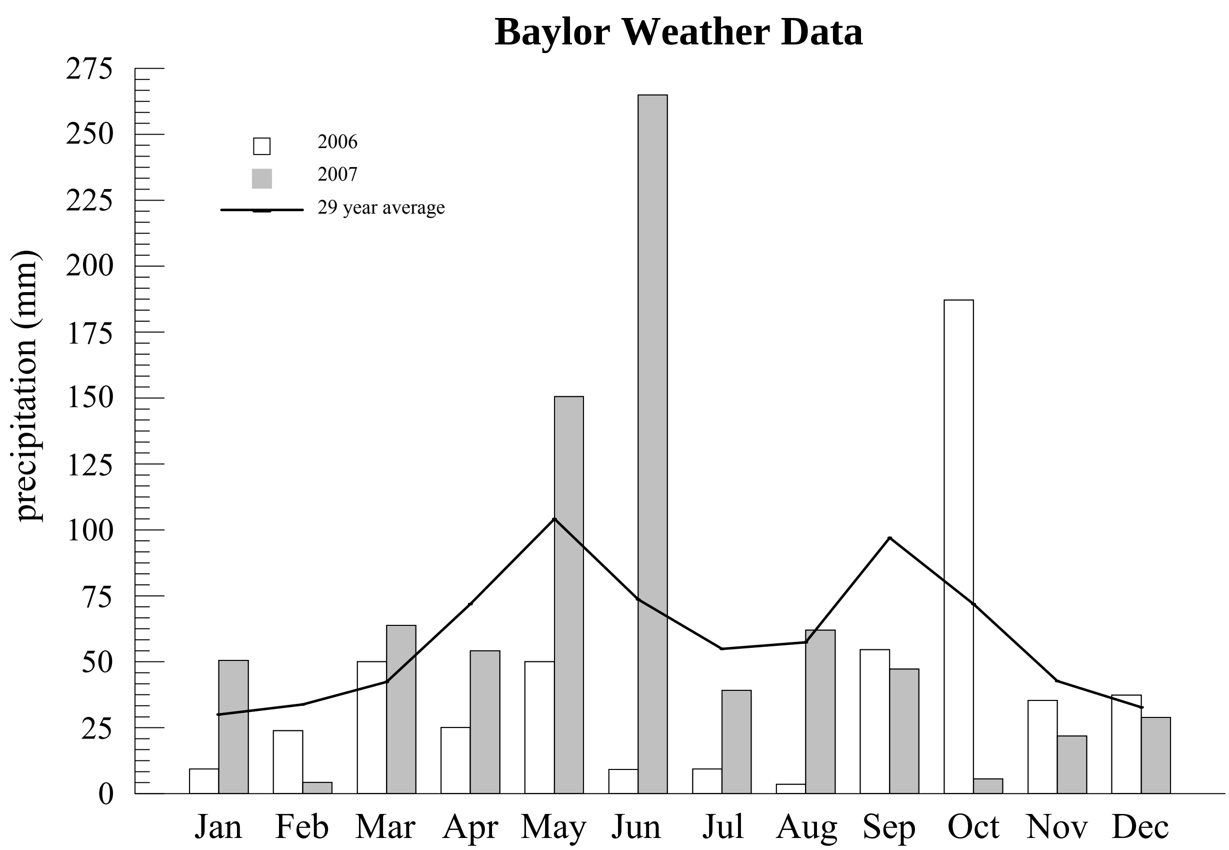

Figure 3-6. Monthly (2006-2007) and monthly average (1971-2000) precipitation in millimeters (mm) at Lake Kemp, Texas, weather station, located about 19 km from the sandy study site and 38 km from the clay study site.

3.1.3 Kleberg County

Kleberg County is on a grassy plain in the South Texas Plains ecoregion covering over 220,925 ha (Handbook of Texas Online 2008). The Delfina soil series dominates the sandy soil study site and consists of fine-loamy, mixed, superactive, hyperthermic Typic Paleustalfs (USDA-NRCS 2007a) with elevations ranging from 15 to 91 m (Soil Survey Staff, NRCS 2008) (Fig. 3-7). The dominant soil order for this county is Vertisol (Soil Survey Staff, NRCS 2006), with Delfina soils making up 95% of this study site containing a surface layer of brown fine sandy loam about 38.1 cm thick and the remaining 5% consisting of Carreta soil. The Victoria clay soil series, fine, smectitic, hyperthermic Sodic Haplusterts (USDA-NRCS 2006b), dominates the clay soil study site with an elevation ranging from 6.1 to 37 m (Soil Survey Staff, NRCS 2008) (Fig. 3-8). Victoria soils make up 72.5% of this study site with a surface layer of clay about 30.5 cm thick with the remaining 27.5% consisting of Cranell sandy clay loam (Soil Survey Staff, NRCS 2008).

Figure 3-7. Study site in Kleberg County, Texas, on sandy soil.

Figure 3-8. Study site in Kleberg County, Texas, on clay soil.

Kleberg County has a mean annual (1971-2000) rainfall of 61.44 mm (NOAA 2008c) with a mean annual temperature of 35.6 ºC (Fig. 3-9) (Handbook of Texas Online 2008). The prevailing winds in this area are from the southeast the majority of the year (Soil Survey Staff, NRCS 2008). Characteristic grasses of the sandy loam soils are seacoast bluestem (*Schizachyrium littorale* (Nash) E.P. Bicknell), bristlegrass (*Setaria* P. Beauv.), paspalums (*Paspalum* sp.), windmillgrasses, silver bluestem (*Bothriochloa saccharoides* (Sw.) Rydb.), big sandbur (*Cenchrus myosuroides* Kunth), and tanglehead (*Heteropogon contortus* (L.) P. Beauv. ex Roem. & Schult.). The dominants on the clay and clay loams are silver bluestem, Arizona cottontop (*Digitaria californica* (Benth.) Henr.), buffalograss, common curlymesquite, and species of Setaria, Pappophorum, and Bouteloua. The introduced species buffelgrass (*Pennisetum ciliare* (L.) Link) has proliferated and is common on loamy to sandy soils in the western half of the area. Bermudagrass, kleingrass (*Panicum coloratum* L.), and Rhodes grass (*Chloris gayana* Kunth) are also common introduced species in this area (Hatch and Pluhar 1993).

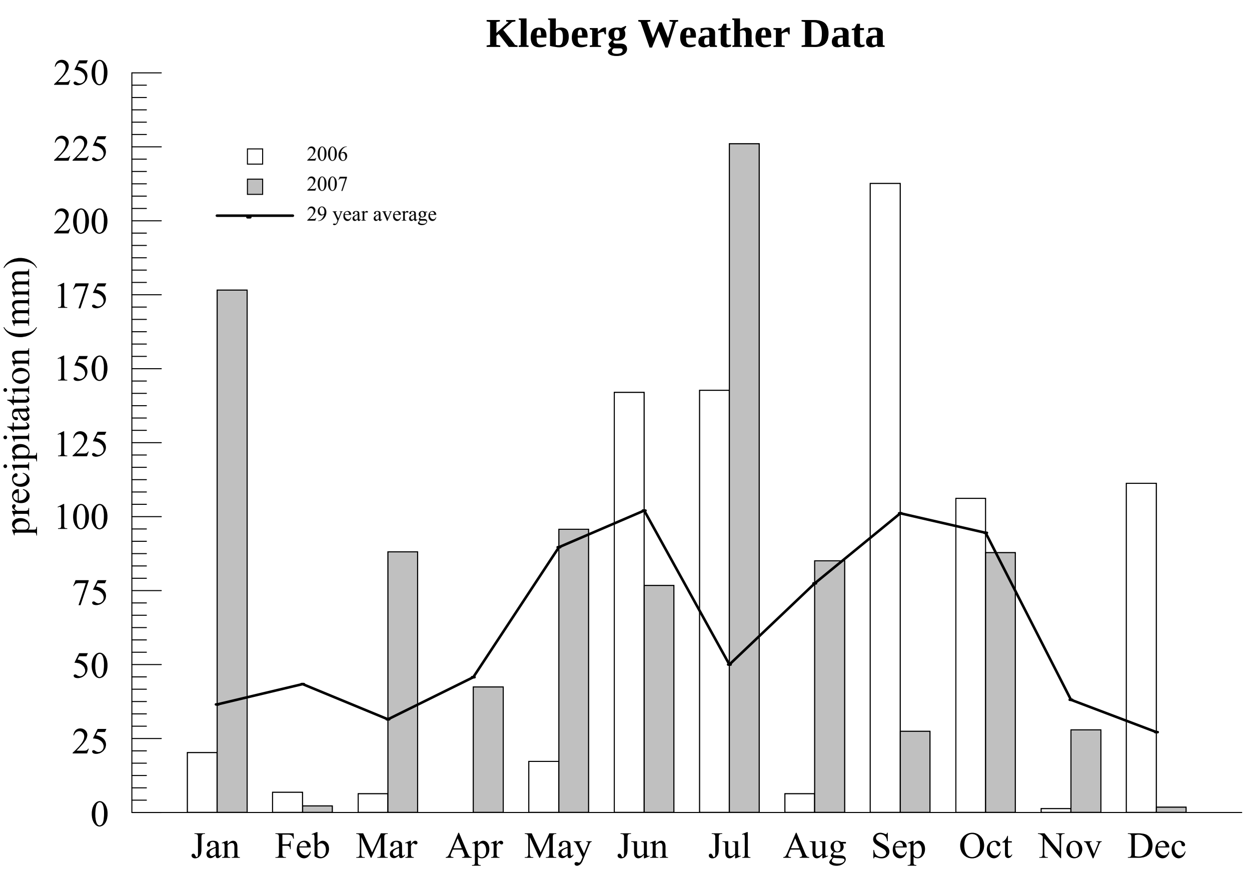

Figure 3-9. Monthly (2006-2007) and monthly average (1971-2000) precipitation in millimeters (mm) at Padre Island National Seashore, Texas, weather station, located approximately 56 km from the study sites.

3.2 Experimental Design

At each location, an experimental site was established on two different soil textures, except at Andrews County, where only sandy soil was available. Within each county and soil texture, treatments were randomly assigned within each of four blocks. Plot boundaries were established with wooden stakes and colored markers. Experimental plots (3 m × 6 m) were separated by a 1.5 m buffer to avoid edge effects. Reference plots were also established near the experimental units and were used to compare percent canopy cover at each evaluation period. Experiments included planting TxDOT's standard seed mixture recommended for each district and was compared against a native seed mixture and a combination of the two mixes; a monoculture of hooded WMG accession numbers 9085301 or 9085313, shortspike WMG accession numbers 9085260 or 9085283, and bermudagrass, with the use of a soil retention blanket; a monoculture of four accessions of native WMGs and bermudagrass; and the comparison of two common seeding techniques: drill seeding versus broadcasting (Fulbright et al. 1998). Pictures of each plot were taken at 30, 60, and 90 day evaluations for each location and year to visually record the progress of the project over time. Low rainfall during 2006 necessitated repeated plantings during 2007 in Baylor and Kleberg Counties to achieve a successful stand (Fig. 3-3, Fig. 3-6, and Fig. 3-9) (Fulbright et al. 1998).

3.2.1 Revegetating Texas Roadsides with Native Seed Mixtures

The experimental design was a randomized, complete-block with four blocks on sandy soils and four blocks on clay soils. Three treatments were randomly assigned within each block: 1) TxDOT's standard permanent rural seed mixture, 2) a native seed mixture including hooded and shortspike WMGs, and 3) a combination of the standard and native seed mixes. Experimental units (treatment and block combinations) were 3 × 6 m and were separated by a 1.5 m buffer.

TxDOT's standard permanent rural seed mixture for Andrews County on sandy soils included: green sprangletop (0.61 g·m²), "Hachita" blue grama (1.62 g·m²), "Ermelo" weeping lovegrass (1.22 g·m²), sand dropseed (0.81 g·m²), purple prairie clover *Dalea purpurea* Vent. (1.02 g·m²), and Indian ricegrass *Achnatherum hymenoides* (Roem. & Schult.) Barkworth (6.06 g·m²) (TxDOT 2004).

The standard seed mixture for Baylor County on sandy soils included: green sprangletop (0.61 g·m²), bermudagrass (2.42 g·m²), sand bluestem (4.85 g·m²), sand dropseed (0.81 g·m²), sand lovegrass *Eragrostis trichodes* (Nutt.) Alph. Wood (0.61 g·m²), "Ermelo" weeping lovegrass (1.21 g·m²), and purple prairie clover (1.02 g·m²). The clay mixture consisted of: green sprangletop (0.61 g·m²), bermudagrass (1.82 g·m²), "El Reno" sideoats grama (5.46 g·m²), "Texoka" buffalograss (3.23 g·m²), western wheatgrass (4.24 g·m²), blue grama (1.21 g·m²), and Illinois bundleflower *Desmanthus illinoensis* (Michx.) MacMill. ex B.L. Rob. & Fernald (2.03 g·m²) (TxDOT 2004).

The standard seeding mixture for Kleberg County on sandy soil included: green sprangletop (0.61g·m²), bermudagrass (3.65 g·m²), buffelgrass (0.81 g·m²), sand lovegrass (1.22 g·m²), Lehmann lovegrass *Eragrostis lehmanniana* Nees (1.21 g·m²), and purple prairie clover (1.02 g·m²). The clay mixture consisted of: green sprangletop (0.61 g·m²), bermudagrass (3.65 g·m²), "Haskell" sideoats grama (5.46 g·m²), "Texoka" buffalograss (3.65 g·m²), plains bristlegrass *S. vulpiseta* (Lam.) Roem. & Schult. (2.43 g·m²), and Illinois bundleflower

(2.03 g·m²). In addition, Kleberg bluestem *Dichanthium annulatum* (Forssk.) Stapf was included in both seeding mixtures (1.62 g·m²) on sandy and clay soils in Kleberg County (TxDOT 2004).

Data were analyzed using analysis of variance for repeated measures using absolute percent canopy cover of vegetation, windmillgrass canopy cover, bermudagrass canopy cover, and total canopy cover as dependent variables, while treatments (three levels) were used as independent variables (PROC GLM, SAS Institute, Inc. 2007). Pairwise comparisons among means were computed using Tukey's Studentized Range (HSD) test when the plot treatments were significant ($P < 0.05$) (SAS Institute, Inc. 2007). Data were analyzed by site and year because of a general lack of homogeneity of variances among these factors (Sheley and Carpinelli 2005).

3.2.2 Establishing Roadside Vegetation with Soil Retention Blankets

The experimental design was a randomized, split-block with 20, 3 × 6 m plots separated by a 1.5 m buffer. The experiment consisted of 5 plots, each seeded with a single species, and replicated 4 times on clay and 4 times on sandy soils. This two-year experiment was conducted along roadsides in Andrews, Baylor, and Kleberg Counties. The North American Green® single net straw blanket was chosen for this study based on TxDOT's approved product list of SRBs. This SRB had a layer of 100% straw fiber stitched with biodegradable thread to a biodegradable, natural-fiber top net, providing erosion protection and assisting with vegetation establishment for up to 12 months. The protective mulch provided by the blanket help create optimal conditions needed for seeds to germinate and grow (North American Green 2008). This single net straw blanket (S75BN™) was rolled over the plots to obtain about 50% cover and staked into the ground to hold the blanket in place (North American Green 2008) (Fig. 3-10). Additional SRBs were not installed on any plots during 2007.

Figure 3-10. Single net straw blanket (S75BN™) from North American Green© in Andrews County, Texas, 2006.

Analyses were conducted using the PROC MIXED command in SAS with the Kenward-Rogers option using absolute percent canopy cover of vegetation, windmillgrass canopy cover, bermudagrass canopy cover, and total percent vegetation canopy cover as dependent variables, while treatments (5 levels) and SRB (2) were used as independent variables (Littell et al. 1996; Fulbright 2004; PROC MIXED, SAS Institute, Inc. 2007). The least-squares means procedure with the Tukey adjustment was used to compare means when the plot treatments or TRT × SRB interaction were significant ($P < 0.05$) (SAS Institute, 1989; Fulbright 2004). Data were analyzed by site and year because of a general lack of homogeneity of variances among these factors (Sheley and Carpinelli 2005).

3.2.3 Native Alternatives to Introduced Species

The experimental design was a randomized, complete-block with 20, 3 × 6 m plots separated by a 1.5 m buffer. The experiment consisted of 5 plots, each seeded with a single species, and replicated 4 times on clay and 4 times on sandy soils. This two-year experiment was conducted along roadsides in Andrews, Baylor, and Kleberg Counties.

Figure 3-11. USDA, NRCS, "Kika" de la Garza Plant Materials Center ATV seed drill.

Analyses were conducted using the PROC GLM command in SAS using absolute vegetation canopy cover, windmillgrass canopy cover, bermudagrass canopy cover, and total vegetation canopy cover as dependent variables, while treatments (5 levels) were used as independent variables (PROC GLM, SAS Institute, Inc. 2007). The least-squares means procedure with the Tukey adjustment was used to compare means when plot treatments were significant ($P < 0.05$) (SAS Institute, 1989; Fulbright 2004). Data were analyzed by site and year because of a general lack of homogeneity of variances among these variables (Sheley and Carpinelli 2005).

3.2.4 Assessment of Two Commonly Used Seeding Techniques

The experimental design was a randomized, complete-block with 8, 3 × 6 m plots separated by a 1.5 m buffer. Each experimental unit consisted of 4 plots that were broadcasted with seeds and 4 plots that were drilled with seeds using a Tye® grass drill seeder pulled by a 7610 Ford tractor (70 HP). Treatments were randomly assigned within each block and replicated 4 times on clay and 4 times on sandy soils. Green sprangletop (*Leptochloa dubia* (Kunth) Nees), bermudagrass, hooded and shortspike WMG were the species chosen for this experiment. This one-year experiment was conducted along roadsides in Kleberg County only.

Analyses were conducted using the PROC GLM command in SAS using absolute vegetation canopy cover, windmillgrass canopy cover, bermudagrass canopy cover, and total vegetation canopy cover as dependent variables, while treatments (2 levels) were used as independent variables (PROC GLM, SAS Institute, Inc. 2007). The least-squares means procedure with the Tukey adjustment was used to compare means when plot treatments were significant ($P < 0.05$) (SAS Institute, 1989; Fulbright 2004).

3.3 Plot Preparation

Experimental plots in Andrews, Baylor, and Kleberg Counties were treated on 27 April 2006, 19 April 2007, and 14 February 2006, respectively, with 0.95 $L \cdot ha^{-1}$ Cornerstone™ with the active ingredient glyphosate, a non-selective, foliar applied herbicide, [N-(phosphonomethyl)glycine] (Venable 2005) combined with 1.05 $L \cdot ha^{-1}$ of Preference®, with the active ingredient nonionic surfactant (Winfield Solutions 2008) applied with a Wylie Boom pulled by an ATV. In Kleberg County, this mixture was applied with a Wylie Boom pulled by a 7610 Ford tractor (70 HP).

In Andrews County, all experimental plots were re-treated with the Cornerstone™ and Preference® mixture on 11 May 2006, with the same equipment and at the same rates previously mentioned. Experimental plots were re-staked on 25-26 April 2007.

In Baylor County, all experimental plots were re-treated on 12 May 2006, with 0.854 $L \cdot ha^{-1}$ of glyphosate (Roundup Original Max®) by a 15 L Field King backpack sprayer equipped with an 80º Flat Fan brass nozzle. The plots were then disked on 17 May 2006, with a 203 cm wide Massey-Ferguson tandem disc with 44.5 cm blades pulled by a 970 John Deere tractor (35 HP). Experimental plots were staked out 18 May 2006. Experimental plots were re-staked on 19 April 2007.

In Kleberg County, plots were disked on 30 March 2006, with a 183 cm wide scalloped disc with 51 cm blades pulled by a 7610 Ford tractor (70 HP). Experimental plots were re-sprayed on 14 April 2006, with the Cornerstone™ and Preference® mixture using the same equipment and same rates previously mentioned. Plots were then staked out 14 April 2006. Experimental plots were re-staked on 4-5 April 2007, followed by an application on 6 April 2007, of 0.95 $L \cdot ha^{-1}$ Cornerstone™ with the active ingredient glyphosate, combined with 1.05 $L \cdot ha^{-1}$ of Preference®, a nonionic surfactant (Winfield Solutions 2008) applied with a Wylie Boom pulled by an ATV.

3.4 Germination and Pure Live Seed Calculations

The species planted in this study were selected based on TxDOT's *Guide to Roadside Vegetation Establishment* manual for permanent rural seed mixtures on roadsides (Table A-2) (TxDOT 2004). Germination tests were performed on these species at the "Kika" de la Garza Plant Materials Center in Kingsville, Texas, during April and May 2006 and during April 2007 (Table A-3). Seeds were germinated in clear box containers measuring 13 × 13 × 3.5 cm with tight fitting lids. The substrate for each germination box contained two sheets of Kimpack 14 ply cellulose paper and one layer of blue blotter paper (both from Anchor Paper Co., St. Paul, Minnesota) (Herrera-Cedano et al. 2006). The sheets were moistened with distilled water and 100 randomly selected seeds were placed inside the boxes. This process was replicated 4 times per species. Species with larger seeds, such as sideoats grama, were reduced to 50 seeds per box and replicated 8 times.

Boxes containing grass species were placed into germination chambers where the conditions were 12-hours dark at 20º C and 12-hours light at 30º C based on results reported by Fulbright et al. (1983), Schrauf et al. (1995), and Roundy and Biedenbender (1996) (Herrera-Cedano et al. 2006). Legumes and cool-season species were placed into germination chambers where the conditions were 12-hours dark at 15º C and 12-hours light at 30º C (Maher 2006; AOSA 2007). In 2006, germination counts were made every day for 28 days, starting on day 3. Due to time constraints experienced during 2007, germination counts were made every day for 14 days, starting on day 3. Seeds were considered germinated if both radicle and coleoptile exceeded the seed in length; seedlings were removed as they were counted (Herrera-Cedano et al. 2006). Species for this experiment were obtained from the following sources: "Kika" de la Garza Plant Materials Center, Knox City Plant Materials Center, Aberdeen Plant Materials Center, Los Lunas Plant Materials Center, Turner Seed Company, Douglass W. King Seed Company, Pogue Agri Partners, Curtis & Curtis INC., and Native American Seed.

Pure live seed (PLS) is the product of the purity (the percentage of the lot by weight that consists of the crop seed) and percentage germination as performed by an official germination test (Copeland and McDonald 1995; Jones and Young 2005). During 2006 and 2007, the recommended seeding rates for each county according to TxDOT's recommendations were used for the native seed mixture experiment (Table A-4). During 2006, the recommended seeding rates for critical areas of 40 PLS/0.09 m^2 were used for the soil retention blanket experiment and monoculture experimental plots (USDA-NRCS 2006a). In 2007, since plots were broadcasted, seeding rates for these two experiments were increased to 80 PLS/0.09 m^2, and were intended to promote rapid establishment and homogenous stands (Bugg et al. 1997).

The USDA-NRCS (2006a) recommends higher seeding rates when broadcasting because fewer seeds will end up at optimum burial depth. Brown and Amacher (1999) have also recommended higher seeding rates be used, especially on harsh sites where conditions are particularly limiting to assure adequate seedling densities to minimize surface erosion and sediment movement. Sheley et al. (1999) believed that revegetation success can be enhanced by increasing seeding rates. Sheley and Half (2006) reported in their study that increasing either water frequency or seed density increased establishment of native grasses after two years (Sheley et al. 1999). Their study suggests that high seeding rates can help overcome the effect of weed competition and increase the probability of desirable seeds reaching safe sites (Sheley et al. 1999). The seeding rates for the drill versus broadcast study are also listed in Table A-4.

3.5 Planting Procedures

In 2006 and 2007, all experimental plots were broadcasted by hand in the revegetating Texas roadsides with native seed experiment, taking care to provide even cover to each plot with the seed mixture (Cox and Anderson 2004). The species and seeding rates used in this study were based on TxDOT's *Guide to Roadside Vegetation Establishment* manual for permanent rural seed mixtures on roadsides (TxDOT 2004). The amount of bulk grams·m^2 used per species, in order to meet TxDOT's recommended pure live seed rates, was based on the percent germination acquired in our tests ran in 2006-2007 (Table A-2).

In 2006, monoculture plots were planted with an ATV seed drill in Andrews County. This seeder allows for a maximum furrow-opening depth of 2.5 cm. This seeder has 22.5 cm row spacing with four units mounted to the chassis (USDA-NRCS 2007b) (Fig. 3-11). A Kincaid cone planter with 25 cm spacing pulled by a 970 John Deere tractor (35 HP) was used to plant the monoculture plots in Baylor County, and a Tye® grass drill seeder pulled by a 7610 Ford tractor (70 HP) was used for planting plots in Kleberg County. Since low rainfall was experienced during 2006, plantings were repeated in 2007 by manually broadcasting the seeds over each plot to achieve a successful stand (Fulbright et al. 1998) (Fig. 3-3, Fig. 3-6, Fig. 3-9).

Plots in Andrews County were planted on 29 August 2006. In Baylor County, plots were planted on 23 May 2006 and were replanted on 19 April 2007 because drought during 2006 inhibited plant establishment. Planting occurred on 17-19 April 2006 in Kleberg County and plots were re-seeded on 6 April 2007.

3.6 Sampling Techniques

The point intercept method was used to estimate percent canopy cover of vegetation within each treatment and replication 30, 60, and 90 days after planting at all locations and soil types. Reference plots located adjacent to treatment plots were also evaluated at the same time to account for existing canopy cover typical of that location. Thirty, 60, and 90 day post-planting evaluations were conducted based on recommendations from EPA for semi-arid areas until final stabilization was achieved. Sampling was conducted at 30 day intervals to determine when final stabilization of the study site was achieved in regards to obtaining 70% vegetative cover when compared to adjacent reference plots (EPA 2008).

Sampling was carried out by centering a 60 m measuring tape in the middle of each plot. A 1.5 × 3 m sampling frame was positioned perpendicular to the tape beginning at the 1 m mark to avoid any possible edge effects. Point intercept readings were taken every 20 cm by lowering a 0.3175 cm diameter metal pole through the sampling frame. Subsequent transects continued at 0.5 m intervals along the measuring tape containing 10 points within each transect and 10 transects per plot.

In Andrews County, 30 day evaluations took place on 13-14 October 2006; 60 day evaluations for were completed on 18-19 November 2006; and 90 day evaluations were conducted 16-17 December 2006. On 25-26 April 2007, an additional vegetation assessment was conducted to determine if re-seeding was necessary by running transects through the WMG plots and counting random number of WMG clumps per m^2. A 365 day evaluation took place on 10 October 2007.

In Baylor County, 30 day evaluations were conducted on 21-23 July 2006; 60 Day evaluations were completed 21-23 August 2006; and 90 day evaluations were conducted 23-24 September 2006. The 30 day evaluations for were conducted 9-10 June 2007; 60 day evaluations were completed 14-15 July 2007; and 90 day evaluations were conducted 17-18 August 2007.

In Kleberg County, 30 day evaluations were conducted 14-16, 19-20 June 2006; 60 day evaluations were completed 13-14, 17-19 July 2006; and 90 day evaluations were completed 14-17 August 2006. The 30 day evaluations were conducted on 10-12 June 2007; 60 day evaluations were completed 11-13 July 2007; 90 day evaluations were completed 13-15 August 2007 (Fig. 3-12).

Figure 3-12. Point intercept frame used for evaluations to estimate canopy cover.

During 2007, samples from the mowing regimens were obtained by measuring the width and height, including reproductive structures, (cm^2) of three random WMG clumps within the soil retention blanket experiment and monoculture experimental plot studies located only at the Kleberg County study sites. Plots planted with hooded or shortspike WMG were only used in this evaluation. Data obtained from these measurements will help to quantify the long-term results provided by WMGs in these experiments. Data from the mowing regimens were analyzed for simple descriptive statistics (PROC MEANS, SAS Institute, Inc. 2007).

3.7 Supplemental Irrigation

In semiarid environments, such as Texas, high rainfall variability makes restoration especially challenging (Aronson et al. 1993; Le Houérou 2000; Bochet and García-Fayos 2004). The dynamics of Texas plant communities are driven by variables such as successive years of drought or those of above-normal rainfall (Glasscock et al. 2005). Due to the extreme drought-like weather experienced in Kleberg County during 2006, supplemental irrigation was performed on all experiments (Fig. 3-9). Since the availability of a water source was within a close proximity to the study sites, the experimental plots were watered on both soil types by a tractor carrying a water tank. The plots were watered for six days after the initial planting to facilitate germination and establishment. The study sites located in Andrews and Baylor Counties did not receive watering due to the lack of a close water source.

Five box containers, measuring 13 × 13 × 3.5 cm, were randomly placed within each plot to measure the amount of water received per plot. The water amount in each box was measured with a graduated cylinder (mL). The mean volume of water was averaged across six days for each treatment and soil type. Data from the supplemental irrigation were analyzed for simple descriptive statistics (PROC MEANS, SAS Institute, Inc. 2007).

3.8 Soil Samples

Soil characteristics can have strong impacts on plant establishment and growth, sometimes overshadowing the effects of seeding method (Montalvo et al. 2002). A soil analyses were conducted to characterize the chemical properties that may be limiting to plant establishment and growth (Brown and Amacher 1999). In 2007, soil samples were taken from the upper 10 cm of soil, at 6 different locations, within each plot using a 2 cm diameter soil probe. Samples were then dried at 40º C to a constant mass. Samples were thoroughly mixed once the samples were dried and sieved through a 5 mm mesh screen to remove rocks, litter, and other debris. Soil samples were analyzed for pH, conductivity (umol/cm), nitrate-nitrogen (NO3-N), and soil nutrients including phosphorus, potassium (K), calcium (Ca), magnesium (Mg), sulfur (S), and sodium (Na) (ppm).

The soil pH was determined using a hydrogen selective electrode and conductivity was estimated using a conductivity probe (Schofield and Taylor 1955; Wiemers 2007). Nitrate-nitrogen (NO3-N) was evaluated using a 1 N KCL solution. The reduction of nitrate to nitrite was estimated by the use of a cadmium column, and then followed by a spectrophotometer measurement (Keeney and Nelson 1982; Wiemers 2007). Mehlich III extractant using the inductively couples plasma (ICP) method was used for determining phosphorous, K, Ca, Mg, S, and Na (Mehlich 1978; Mehlich 1984; Wiemers 2007). Data from the soil chemical properties were analyzed for simple descriptive statistics (PROC MEANS, SAS Institute, Inc. 2007).

3.9 Mowing

Mowing along rights of way was carried out by TxDOT contractors as part of their routine maintenance to improve visibility by keeping the vegetation below a height that would compromise safety (Laursen 1981; Forman et al. 2003; TxDOT 2004). The mowing regimen was based on TxDOT's *Roadside Mowing Specifications* (1993) manual and was incorporated at the Kleberg County study site on clay and sandy soils (Table 3-9). During September and November 2007, three WMG stands were randomly chosen within each single species plot of WMG, where the width and height of each plant was measured (cm^2). Data from the mowing regimen were analyzed for simple descriptive statistics which indicated the area (cm^2) occupied by the random WMGs measured per treatment (PROC MEANS, SAS Institute, Inc. 2007).

In Andrews County, plots were mowed 26 April 2006, at 13 cm in height. Plots were also mowed on 20 April, 24 May, and 23 August 2007, at 18 cm in height (Table 3-9). Plots were mowed 17-19 July and 5 August 2006 at 13 cm in height in Baylor County. Plots were also mowed 9 April, 21 May, 18-19 June, 17-19 July, and 5 August 2007 at 13 cm in height (Table 3-9). In Kleberg County, plots were mowed 25 July, 5 September, and 31 October 2006 at 13 cm in height. Plots were also mowed 4-5 April, 23 May, 25-26 June, and 21 September 2007 at 13 cm in height (Table 3-9).

Table 3-9. Mowing and evaluation dates at all study sites during 2006-2007.

2006	Evaluation date	Mowing date	Height[1]
Andrews County	13-14 October	26 April	13
	18-19 November		
	16-17 December		
Baylor County	21-23 July	3 August	13
	21-23 August	1 November	13
	23-24 September		
Kleberg County	14-16 & 19-20 June	25 July	13
	13-14 &17-19 July	5 September	13
	14-17 August	31 October	13
2007			
Andrews County	10 October	20 April	18
		24 May	18
		23 August	18
Baylor County	9-10 June	21 May	13
	14-15 July	18-19 June	13
	17-18 August	17-19 July	13
		5 August	13
Kleberg County	10-12 June	4-5 April	13
	11-13 July	23 May	13
	13-15 August	25-26 June	13
		21 September	13

[1]Height measured in cm.

4. RESULTS

Mowing of experimental plots before canopy cover estimates resulted in an increase in the amount of litter present during that evaluation (Table 3-9). Therefore, caution must be taken when interpreting data due to mowing that occurred previous to some sampling dates (Thompson et al. 2006). During 2006, the study sites experienced extremely dry conditions. Water limitation was likely a critical factor responsible for the low percent canopy cover at all study sites in 2006. However, the study sites received at least the average annual rainfall during 2007 (Fig. 3-3; Fig. 3-6; Fig. 3-9).

4.1 Revegetating Texas Roadsides with Native Seed Mixtures

Windmillgrass canopy cover was ≤ 5% in all locations, soils, and treatments during 2006. Absolute percent canopy cover of vegetation, WMG, bermudagrass, and total percent canopy cover were similar ($P > 0.05$) among treatments in Andrews and Baylor Counties during 2006 (Table 4-1). Absolute percent canopy cover on sandy soils in Kleberg County 30, 60, and 90 days post-planting was 22%, 3%, and 19% greater ($P < 0.05$) for the standard mix than for the native mixes. Bermudagrass cover was 39% and 30% greater ($P < 0.05$) 30 and 60 days after planting in the standard mix than in the combination mixes; total percent canopy cover was 50% and 26% greater ($P = 0.0065$) for the standard mix 90 days post-planting when compared against the native and combination treatments. Treatment main effects were not significant ($P > 0.05$) in Kleberg County during 2006 on clay soils for absolute percent canopy cover of vegetation, WMG, bermudagrass, and total percent canopy cover. All locations, soils, and treatments during 2006 provided at least 70% absolute canopy cover when compared to adjacent reference plots.

In 2007, windmillgrass canopy cover was 167% greater ($P < 0.05$) in the native and the combination mixes than in the standard mix in Andrews County; however, absolute percent canopy cover and total canopy cover of vegetation were similar ($P > 0.05$) among treatments (Table 4-1). Canopy cover of WMG was greater ($P < 0.05$) in the native and combination mixes than in the standard mix 90 days after planting on sandy soils in Baylor County; absolute percent vegetation canopy cover and total vegetation canopy cover were also greater ($P < 0.05$) in the native and combination mixes than in the standard mix 90 days post-planting. Windmillgrass percent canopy cover was also greater ($P = 0.006$) in the native and combination treatments on clay soils 90 days post-planting; however, absolute percent canopy cover of vegetation, bermudagrass canopy cover, and total percent canopy cover were similar ($P > 0.05$) among treatments. Treatment main effects were not significant ($P > 0.05$) in Kleberg County during 2007 on sandy and clay soils for absolute percent canopy cover of vegetation, WMG, bermudagrass, and total canopy cover. During 2007, Baylor and Kleberg Counties provided at least 70% absolute canopy cover compared to adjacent reference plots for both soil types and on all treatments; however, in Andrews County, the native seed mixture did not meet the 70% canopy cover requirement by 5% during the final evaluation.

Table 4-1. Mean (± SE) absolute percent canopy cover of vegetation, windmillgrass, bermudagrass, and total percent canopy cover for Standard, Native, and Combination seed mixtures at Andrews, Baylor, and Kleberg Counties on sandy and clay soils during 2006-2007 at 30, 60, and 90 day evaluations.

2006		**Reference Plots**[1]	**Standard**	**Native**	**Combination**	$F_{2,6}$	*P*
		% Canopy Cover (Mean ± SE)					
Andrews							
Sandy							
30 Day	Absolute[2]	84 ± 3.2	61 ± 3.6	54 ± 2.3	54 ± 3.3	1.85	0.2368
	WMG[2]	21 ± 10.0	< 1 ± 0.50	3 ± 1.7	3 ± 0.9	1.19	0.3674
	BER[2]	< 1 ± 0.50	1 ± 0.50	< 1 ± 0.30	0	1.00	0.4219
	Total[2]	109 ± 9.1	70 ± 5.4	63 ± 4.8	65 ± 4.4	1.72	0.2569
60 Day	Absolute	79 ± 5.5	64 ± 3.5	59 ± 2.8	67 ± 1.8	2.30	0.1812
	WMG	10 ± 7.8	< 1 ± 0.48	< 1 ± 0.25	1 ± 0.41	0.72	0.5227
	BER	0	0	0	0	-	-
	Total	87 ± 7.0	75 ± 7.1	71 ± 5.7	79 ± 3.3	0.69	0.5369
90 Day	Absolute	67 ± 4.6	59 ± 4.2	58 ± 2.9	62 ± 3.6	1.58	0.2804
	WMG	10 ± 5.4	1 ± 0.71	1 ± 0.48	2 ± 0.48	0.51	0.6232
	BER	4 ± 1.7	0	0	0	-	-
	Total	80 ± 6.3	74 ± 6.4	73 ± 3.8	80 ± 4.1	1.32	0.3341
Baylor							
Sandy							
30 Day	Absolute	60 ± 5.5	43 ± 4.5	49 ± 3.3	38 ± 4.0	2.35	0.1764
	WMG	0	0	< 1 ±0.29	< 1 ± 0.29	1.50	0.2963
	BER	49 ± 5.5	< 1 ± 0.25	0	0	1.00	0.4219
	Total	79 ± 11.5	48 ± 4.5	54 ± 4.9	42 ± 6.6	1.53	0.2914
60 Day	Absolute	12 ± 1.5	27 ± 3.8	30 ± 8.4	34 ± 3.8	0.87	0.4649

	WMG	< 1 ± 0.25	< 1 ± 0.25	0	< 1 ±0.29	1.80	0.2441
	BER	11 ± 1.5	< 1 ± 0.25	0	0	1.00	0.4219
	Total	12 ± 1.5	27 ± 3.8	31 ± 8.5	35 ± 3.7	0.98	0.4295
90 Day	Absolute	79 ± 4.9	67 ± 3.9	63 ± 8.7	68 ± 7.7	0.29	0.7571
	WMG	6 ± 3.3	< 1 ± 0.25	< 1 ± 0.75	< 1 ± 0.50	4.90	0.0547
	BER	59 ± 9.6	< 1 ± 0.25	0	< 1 ± 0.25	1.00	0.4219
	Total	91 ± 7.6	78 ± 4.6	76 ± 12.6	83 ± 11.2	0.26	0.7767
Clay							
30 Day	Absolute	94 ± 1.0	13 ± 3.9	14 ± 4.7	22 ± 7.2	4.25	0.0708
	WMG	0	< 1 ± 0.75	2 ± 1.0	1 ± 0.58	3.21	0.1129
	BER	13 ± 6.0	< 1 ± 0.25	< 1 ± 0.50	5 ± 4.0	1.44	0.3078
	Total	138 ± 7.0	13 ± 3.9	14 ± 4.9	23 ± 7.7	4.79	0.0571
60 Day	Absolute	39 ± 4.4	22 ± 3.6	20 ± 3.6	29 ± 6.8	3.95	0.0803
	WMG	0	0	< 1 ± 0.25	< 1 ± 0.25	0.43	0.6699
	BER	7 ± 5.2	< 1 ± 0.50	< 1 ± 0.75	5 ± 5.3	0.84	0.4758
	Total	39 ± 4.6	24 ± 3.1	21 ± 3.8	32 ± 7.7	3.63	0.0925
90 Day	Absolute	86 ± 2.1	67 ± 7.5	67 ± 5.3	72 ± 8.0	0.48	0.6405
	WMG	0	< 1 ± 0.25	2 ± 1.0	4 ± 1.3	2.68	0.1473
	BER	12 ± 7.0	2 ± 1.7	2 ± 1.4	17 ± 16.3	0.84	0.4769
	Total	112 ± 3.1	84 ± 9.0	85 ± 6.5	89 ± 10.0	0.28	0.7647
Kleberg							
Sandy							
30 Day	Absolute	79 ± 6.6	88^{a} ± 1.9	72^{c} ± 4.9	81^{b} ± 2.6	22.38	0.0017
	WMG	0	0	< 1 ± 0.25	0	1.00	0.4219
	BER	57 ± 10.8	68^{a} ± 7.8	41^{b} ± 9.8	49^{b} ± 7.0	13.82	0.0057
	Total	114 ± 21.7	125^{a} ± 7.6	96^{b} ± 4.9	112^{ab} ± 3.0	8.01	0.0203
60 Day	Absolute	95 ± 1.7	99^{a} ± 0.41	96^{b} ± 0.85	97^{b} ± 1.0	19.86	0.0023
	WMG	0	2 ± 1.4	5 ± 1.5	4 ± 1.2	2.70	0.1456
	BER	60 ± 11.4	77^{a} ± 8.5	49^{b} ± 13.0	59^{ab} ± 8.8	5.70	0.0410
	Total	178 ± 11.8	190 ± 12.3	167 ± 10.6	173 ± 8.8	1.02	0.4157

90 Day	Absolute	63 ± 9.0	75^a ± 8.5	63^b ± 8.7	66^{ab} ± 6.7	5.36	0.0462
	WMG	< 1 ± 0.25	2 ± 0.63	< 1 ± 0.29	< 1 ± 0.29	2.14	0.1985
	BER	43 ± 14.7	49 ± 12.0	24 ± 10.7	31 ± 6.7	2.38	0.1733
	Total	76 ± 13.7	102^a ± 16.5	68^b ± 10.6	81^b ± 10.1	13.09	0.0065
Clay							
30 Day	Absolute	80 ± 7.8	51 ± 3.0	40 ± 5.9	54 ± 11.2	1.91	0.2278
	WMG	4 ± 3.1	0	0	0	-	-
	BER	54 ± 16.0	10 ± 2.8	11 ± 0.63	17 ± 4.0	2.67	0.1478
	Total	103 ± 18.0	59 ± 2.2	45 ± 7.1	67 ± 15.4	1.94	0.2243
60 Day	Absolute	89 ± 4.9	99 ± 0.48	99 ± 0.75	99 ± 0.25	0	1.00
	WMG	2 ± 2.3	1 ± 1.0	2 ± 1.2	1 ± 0.41	0.33	0.7290
	BER	59 ± 15.8	29 ± 7.5	22 ± 2.8	40 ± 7.9	2.38	0.1738
	Total	124 ± 18.6	172 ± 19.2	170 ± 8.2	180 ± 9.8	0.23	0.8036
90 Day	Absolute	55 ± 16.5	50 ± 2.9	51 ± 3.2	53 ± 10.4	0.05	0.9556
	WMG	3 ± 1.2	< 1 ± 0.50	< 1 ± 0.25	< 1 ± 0.29	0.43	0.6699
	BER	41 ± 18.8	2 ± 1.1	4 ± 1.3	10 ± 6.5	1.19	0.3664
	Total	62 ± 20.1	51 ± 3.2	54 ± 3.6	62 ± 16.0	0.28	0.7664
2007							
Andrews							
Sandy							
Final	Absolute	61 ± 2.3	44 ± 2.2	41 ± 3.9	43 ± 2.5	0.50	0.6314
	WMG	18 ± 3.2	6^b ± 3.1	16^a ± 2.5	16^a ± 2.1	7.87	0.0210
	BER	< 1 ± 0.38	4 ± 0.96	2.0 ± 0.71	4 ± 0.85	1.00	0.4219
	Total	71 ± 3.5	51 ± 4.0	51 ± 5.4	53 ± 4.9	0.21	0.8149
Baylor							
Sandy							
30 Day	Absolute	99 ± 0.62	67 ± 5.3	73 ± 4.8	75 ± 4.4	1.38	0.3219
	WMG	2 ± 0.77	< 1± 0.48	6 ± 2.8	13 ± 3.9	4.49	0.0643
	BER	70 ± 12.4	< 1 ± 0.25	< 1 ± 0.29	< 1 ± 0.25	1.80	0.2441
	Total	265 ± 42.7	86 ± 9.6	96 ± 8.2	101 ± 9.6	1.43	0.3104
60 Day	Absolute	95 ± 1.9	93 ± 1.3	94 ± 1.7	94 ± 2.3	0.19	0.8294

	WMG	2 ± 0.73	2^b ± 0.96	12^b ± 2.6	25^a ± 5.6	17.13	0.0033
	BER	78 ± 4.5	< 1 ± 0.25	0	0	1.00	0.4219
	Total	141 ± 7.07	140 ± 8.6	144 ± 3.3	149 ± 7.0	1.66	0.2672
90 Day	Absolute	41 ± 6.1	38^b ± 3.6	53^a ± 5.5	52^a ± 5.5	6.63	0.0303
	WMG	4 ± 3.7	0^b	16^a ± 4.7	23^a ± 3.3	15.38	0.0043
	BER	37 ± 5.0	0	0	0	-	-
	Total	43 ± 6.2	41^b ± 4.8	64^a ± 2.0	59^a ± 7.2	13.96	0.0055
Clay							
30 Day	Absolute	99 ± 0.31	48 ± 1.3	57 ± 3.8	62 ± 7.2	3.09	0.1197
	WMG	0	< 1 ± 0.25	6 ± 2.9	9 ± 2.6	2.56	0.1575
	BER	14 ± 2.8	5 ± 1.7	4 ± 2.2	20 ± 13.8	1.24	0.3551
	Total	170 ± 5.3	55 ± 1.6	64 ± 3.8	73 ± 10.6	2.22	0.1895
60 Day	Absolute	100 ± 0.27	78 ± 5.1	82 ± 2.7	78 ± 3.4	0.60	0.5793
	WMG	0	1 ± 0.58	10 ± 2.2	9 ± 3	4.91	0.0545
	BER	29 ± 4.0	13 ± 6.9	13 ± 7.0	29 ± 16.4	0.74	0.5155
	Total	140 ± 4.4	96 ± 9.1	105 ± 6.1	96 ± 4.5	1.89	0.2303
90 Day	Absolute	83 ± 1.5	89 ± 3.4	89 ± 2.3	88 ± 4.3	0.07	0.9292
	WMG	0	< 1^b ± 0.48	18^a ± 1.5	15^a ± 4.4	13.43	0.0061
	BER	13 ± 4.1	18 ± 8.1	13 ± 6.8	34 ± 17.8	0.72	0.5225
	Total	113 ± 3.5	140 ± 18.8	136 ± 9.7	127 ± 13.1	0.71	0.5284
Kleberg Sandy							
	Absolute	90 ± 3.8	88 ± 1.1	86 ± 2.1	86 ± 4.4	0.20	0.8202
30 Day							
	WMG	1 ± 0.50	0	7 ± 4.1	2 ± 0.95	2.94	0.1290
	BER	67 ± 10.6	72 ± 5.0	56 ± 10.0	71 ± 3.5	2.78	0.1398
	Total	114 ± 8.5	109 ± 0.50	117 ± 6.4	115 ± 6.4	0.80	0.4931
60 Day	Absolute	90 ± 3.2	95 ± 2.4	95 ± 1.8	95 ± 1.2	0.12	0.8930
	WMG	< 1 ± 0.30	2 ± 0.96	4 ± 3.7	3 ± 1.9	0.21	0.8195
	BER	65 ± 10.7	76 ± 6.0	67 ± 4.3	57 ± 9.0	1.62	0.2746
	Total	112 ± 10.2	128 ± 3.1	140 ± 7.5	127 ± 6.6	1.50	0.2961

90 Day	Absolute	99 ± 0.70	99 ± 0.95	97 ± 1.1	95 ± 1.4	3.19	0.1139
	WMG	6 ± 3.1	< 1 ± 0.48	2 ± 0.71	3 ± .18	1.15	0.3775
	BER	76 ± 9.2	74 ± 8.2	66 ± 4.1	54 ± 6.3	1.75	0.2518
	Total	145 ± 9.9	179 ± 12.8	188 ± 14.8	154 ± 6.6	2.79	0.1393
Clay							
30 Day	Absolute	94 ± 2.1	85 ± 3.1	94 ± 1.4	92 ± 2.8	2.52	0.1601
	WMG	4 ± 2.8	3 ± 1.7	4 ± 1.6	3 ± 2.4	0.08	0.9203
	BER	83 ± 5.9	51 ± 9.3	52 ± 3.7	64 ± 5.8	1.14	0.3812
	Total	121 ± 7.1	113 ± 3.1	131 ± 0.85	129 ± 8.6	2.85	0.1347
60 Day	Absolute	96 ± 1.8	97 ± 1.3	97 ± 1.2	95 ± 2.4	0.36	0.7106
	WMG	4 ± 2.9	3 ± 0.75	5 ± 0.63	4 ± 1.5	0.81	0.4872
	BER	87 ± 5.6	49 ± 7.4	51 ± 2.3	54 ± 5.7	0.18	0.8426
	Total	118 ± 6.2	129 ± 2.7	133 ± 2.7	124 ± 7.2	0.72	0.5231
90 Day	Absolute	99 ± 0.9	100 ± 0.25	100 ± 0.25	99 ± 0.75	0.43	0.6699
	WMG	4 ± 1.8	7 ± 2.8	6 ± 3.1	7 ± 3.0	0.05	0.9505
	BER	75 ± 7.2	54 ± 3.6	62 ± 3.3	54 ± 6.0	2.40	0.1717
	Total	152 ± 7.1	158 ± 3.0	159 ± 3.1	160 ± 10.4	0.06	0.9420

[1]Means followed by the same letter are not significantly different (Tukey-Kramer adjustment for multiple comparisons of least squares means, $P > 0.05$); reference plots were not included in the statistical analyses with the treatments.
[2]Absolute vegetation canopy cover (%) = 100 - bare ground (%) + rock (%) + litter (%); WMG indicates windmillgrass; BER indicates bermudagrass; Total indicates canopy cover including overlapping species.

4.2 Establishing Roadside Vegetation with Soil Retention Blankets

Seeding treatment × soil retention blanket interactions were not significant ($P > 0.05$) at all geographic locations and soils, except in 2006 at Kleberg County on sandy soil 60 days post-treatment ($P = 0.0090$) (Table 4-2-1; Fig. 3-13). SRB tended to support greater absolute canopy cover than plots with no SRB (Fig. 3-13). Absolute percent canopy cover of vegetation, WMG, bermudagrass, and total percent canopy cover were similar ($P > 0.05$) among seeding treatments in 2006 in all geographic locations and soils. During 2006, in Andrews County, 260 SS WMG and 283 SS WMG treatments did not meet the 70% canopy cover requirement by 4%, 90 days post-planting. Baylor County provided at least 70% absolute canopy cover compared to adjacent reference plots for both soil types and on all treatments. Treatments on sandy soil in Kleberg county also provided at least 70% absolute canopy cover compared to adjacent reference plots at the 90 day evaluation; however, 283 SS WMG, 313 H WMG, and bermudagrass treatments did not meet the 70% canopy cover requirement by 63%, 26%, and 8%, respectively, 90 days post-planting.

Grass accession/species treatment main effects were not significant ($P > 0.05$) during 2007 in Andrews County for absolute percent cover of vegetation, bermudagrass, and total percent canopy cover (Table 4-2-1). Canopy cover of 260 SS WMG was 160% greater ($P = 0.0102$) than bermudagrass canopy cover on sandy soil 365 days post-planting. Grass accession/species treatment main effects were not significant ($P > 0.05$) during 2007 in Baylor County for absolute percent cover of vegetation, bermudagrass, and total percent canopy cover 30, 60, and 90 days post-treatment on sandy and clay soils. Canopy cover of 260 SS WMG, was 325% greater ($P = 0.0155$) than bermudagrass 60 days post-planting and 700% greater ($P = 0.0004$) on sandy soil 90 days post-planting. Canopy cover of 260 SS WMG was 400% greater ($P = 0.0383$) than bermudagrass canopy cover 30 days post-planting, 500% greater ($P = 0.0085$) 60 days post-planting, and 800% greater ($P < 0.0001$) on clay soil 90 days post-planting. Grass accession/species treatment main effects were not significant ($P > 0.05$) during 2007 in Kleberg County for absolute percent cover of vegetation, bermudagrass, and total percent canopy cover 30, 60, and 90 days post-treatment on sandy and clay soils. Canopy cover of 283 SS WMG was 500% greater ($P = 0.0104$) than bermudagrass treatment 30 days post-planting, 1100% greater ($P = 0.0007$) 60 days post-planting, and 1000% greater ($P < 0.0001$) on sandy soil 90 days post-planting. During 2007, in Andrews County, 301 H WMG treatment did not meet the 70% canopy cover requirement by 2%, 90 days post-planting. Baylor and Kleberg Counties did meet EPA's 70% canopy cover requirement, when compared to adjacent reference plots for both soil types and on all treatments.

Table 4-2-1. Mean (± SE) absolute percent canopy cover of vegetation, windmillgrass, bermudagrass, and total percent canopy cover for each seeding treatment with and without the SRB treatment at Andrews, Baylor, and Kleberg Counties on sandy and clay soils during 2006-2007 at 30, 60, and 90 day evaluations.

2006		Reference Plots[1]	260 SS[2]	283 SS[2]	301 H[2]	313 H[2]	BER[2]	$F_{4,12}$	*P*
Andrews		% Canopy Cover (Mean ± SE)							
Sandy									
30 Day	Absolute[2]	84 ± 3.2	45 ± 3.9	41 ± 5.0	49 ± 3.8	50 ± 5.7	42 ± 6.6	0.11	0.9776
	WMG[2]	21 ± 10.0	1 ± 0.30	< 1 ± 0.20	1 ± 0.70	< 1 ± 0.20	1 ± 0.40	0.57	0.6891
	BER[2]	< 1 ± 0.50	0	0	0	0	0	-	-
	Total[2]	109 ± 9.1	52 ± 5.3	45 ± 6.1	52 ± 5.6	57 ± 7.2	49 ± 9.5	0.65	0.6372
60 Day	Absolute	79 ± 5.5	61 ± 4.8	52 ± 4.9	62 ± 4.6	64 ± 6.0	59 ± 6.2	2.01	0.1577
	WMG	10 ± 7.8	1 ± 0.30	1 ± 0.40	< 1 ± 0.20	< 1 ± 0.10	< 1 ± 0.30	2.55	0.0935
	BER	0	< 1 ± 0.10	0	0	0	0	-	-
	Total	87 ± 7.0	68 ± 6.1	58 ± 6.4	69 ± 5.8	74 ± 8.1	70 ± 9.4	1.62	0.2333
90 Day	Absolute	67 ± 4.6	45 ± 3.5	45 ± 4.0	48 ± 3.2	51 ± 3.6	50 ± 3.7	1.26	0.3382
	WMG	10 ± 5.4	1 ± 0.30	1 ± 0.40	< 1 ± 0.10	< 1 ± 0.30	< 1 ± 0.30	1.80	0.1937
	BER	4 ± 1.7	< 1 ± 0.30	0	0	0	0	-	-
	Total	80 ± 6.3	46 ± 3.6	46 ± 4.0	49 ± 3.3	52 ± 3.6	51 ± 3.6	1.71	0.2128
Baylor									
Sandy									
30 Day	Absolute	60 ± 5.5	49 ± 2.3	52 ± 5.5	53 ± 5.2	45 ± 5.8	49 ± 5.7	0.84	0.5250
	WMG	0	0	0	0	0	0	-	-
	BER	49 ± 5.5	0	< 1 ± 0.30	0	0	< 1 ± 0.40	-	-
	Total	79 ± 11.5	53 ± 2.9	59 ± 6.6	64 ± 7.3	52 ± 7.2	54 ± 7.6	1.52	0.2567
60 Day	Absolute	12 ± 1.5	25 ± 3.0	28 ± 4.7	26 ± 4.2	23 ± 3.8	21 ± 2.3	0.79	0.5547
	WMG	< 1 ± 0.25	0	0	0	0	0	-	-
	BER	11 ± 1.5	0	< 1 ± 0.30	0	0	< 1 ± 0.10	-	-
	Total	12 ± 1.5	25 ± 3.2	28 ± 4.7	27 ± 4.7	23 ± 3.9	22 ± 2.3	0.77	0.5643
90 Day	Absolute	79 ± 4.9	64 ± 4.2	64 ± 5.0	63 ± 3.6	66 ± 3.7	58 ± 5.8	0.94	0.4725
	WMG	6 ± 3.3	< 1 ± 0.10	0	< 1 ± 0.10	< 1 ± 0.20	0	1.00	0.4449
	BER	59 ± 9.6	0	1 ± 0.60	< 1 ± 0.30	0	1 ± 0.80	-	-
	Total	91 ± 7.6	71 ± 4.5	70 ± 5.7	73 ± 5.1	75 ± 4.6	65 ± 6.9	0.74	0.5822
Clay									
30 Day	Absolute	94 ± 1.0	18 ± 3.4	11 ± 2.0	21 ± 4.4	22 ± 5.4	22 ± 4.7	1.27	0.3361

	WMG	0	0	0	0	0	0	-	-
	BER	13 ± 6.0	2 ± 0.90	1 ± 0.60	1 ± 0.90	2 ± 1.3	4 ± 2.3	1.11	0.3949
	Total	138 ± 7.0	19 ± 3.5	12 ± 2.2	21 ± 4.5	23 ± 6.0	24 ± 5.5	1.07	0.4131
60 Day	Absolute	39 ± 4.4	55 ± 5.6	39 ± 3.9	42 ± 4.4	49 ± 6.8	55 ± 6.9	2.47	0.1007
	WMG	0	1 ± 0.50	< 1 ± 0.30	0	< 1 ± 0.10	< 1 ± 0.10	1.11	0.3959
	BER	7 ± 5.2	4 ± 1.5	3 ± 1.3	2 ± 1.0	3 ± 1.4	7 ± 4.2	1.23	0.3490
	Total	39 ± 4.6	62 ± 7.8	44 ± 4.8	47 ± 5.3	56 ± 8.8	63 ± 8.1	1.47	0.2726
90 Day	Absolute	86 ± 2.1	92 ± 2.5	84 ± 3.0	88 ± 3.8	88 ± 5.1	87 ± 3.9	1.19	0.3625
	WMG	0	2 ± 0.90	2 ± 0.60	1 ± 0.40	1 ± 0.30	0	2.07	0.1476
	BER	12 ± 7.0	8 ± 3.4	9 ± 4.1	6 ± 3.4	9 ± 2.7	9 ± 4.8	0.42	0.7915
	Total	112 ± 3.1	138 ± 8.3	114 ± 8.0	124 ± 9.4	126 ± 10.3	132 ± 12.8	1.11	0.3962
Kleberg Sandy									
30 Day	Absolute	79 ± 6.6	75 ± 7.1	78 ± 5.6	84 ± 5.6	64 ± 11.2	78 ± 6.1	1.92	0.1719
	WMG	0	0	0	0	0	0	-	-
	BER	57 ± 10.8	9 ± 2.2	13 ± 3.9	9 ± 3.1	8 ± 2.2	10 ± 2.1	0.41	0.7995
	Total	114 ± 21.7	111 ± 15.0	121 ± 15.9	110 ± 13.4	88 ± 18.6	109 ± 12.6	1.52	0.2580
60 Day	Absolute	95 ± 1.7	95 ± 1.6	98 ± 0.80	97 ± 1.5	77 ± 10.9	94 ± 3.3	1.89	0.1764*
	WMG	0	< 1 ± 0.10	< 1 ± 0.10	< 1 ± 0.30	1 ± 0.30	2 ± 1.1	1.75	0.2035
	BER	60 ± 11.4	9 ± 3.3	11 ± 3.5	11 ± 4.6	8 ± 2.2	12 ± 3.3	0.31	0.8626
	Total	178 ± 11.8	159 ± 19.3	164 ± 9.5	147 ± 15.3	117 ± 18.8	162 ± 20.4	1.28	0.3310
90 Day	Absolute	63 ± 9.0	57 ± 9.8	62 ± 6.4	56 ± 10.4	49 ± 8.8	57 ± 9.0	0.63	0.6476
	WMG	< 1 ± 0.25	< 1 ± 0.10	< 1 ± 0.10	0	< 1 ± 0.10	< 1 ± 0.10	0.23	0.9158
	BER	43 ± 14.7	5 ± 2.3	5 ± 1.9	6 ± 2.7	5 ± 2.1	6 ± 1.8	0.27	0.8947
	Total	76 ± 13.7	68 ± 14.2	75 ± 10.3	67 ± 15.5	53 ± 9.7	67 ± 12.2	1.05	0.4241
Clay									
30 Day	Absolute	80 ± 7.8	60 ± 5.3	52 ± 7.6	60 ± 5.5	58 ± 6.5	63 ± 6.3	0.77	0.5642
	WMG	4 ± 3.1	0	0	0	0	0	-	-
	BER	54 ± 16.0	4 ± 1.7	1 ± 0.30	2 ± 0.60	1 ± 0.60	3 ± 1.8	1.33	0.3142
	Total	103 ± 18.0	74 ± 7.5	59 ± 9.1	69 ± 6.2	70 ± 7.7	74 ± 8.4	0.94	0.4760
60 Day	Absolute	89 ± 4.9	92 ± 3.9	96 ± 2.3	95 ± 1.9	95 ± 2.2	94 ± 1.7	0.37	0.8241
	WMG	2 ± 2.3	0	0	0	0	0	-	-
	BER	59 ± 15.8	9 ± 3.3	4 ± 1.6	5 ± 1.7	5 ± 1.7	4 ± 1.2	1.48	0.2700
	Total	124 ± 18.6	150 ± 14.4	144 ± 5.1	137 ± 9.8	154 ± 11.0	148 ± 8.6	0.83	0.5286

90 Day	Absolute	55 ± 16.5	49 ± 10.6	24 ± 5.6	48 ± 10.8	31 ± 6.9	36 ± 10.6	1.56	0.2464
	WMG	3 ± 1.2	0	0	< 1 ± 0.10	0	< 1 ± 0.10	-	-
	BER	41 ± 18.8	5 ± 2.7	1 ± 0.60	5 ± 2.0	2 ± 0.50	1 ± 0.50	1.64	0.2288
	Total	62 ± 20.1	62 ± 17.0	25 ± 5.8	59 ± 15.0	32 ± 6.7	37 ± 10.8	1.61	0.2362
2007									
Andrews Sandy									
Final	Absolute	61 ± 2.3	50 ± 3.0	49 ± 2.8	42 ± 5.5	44 ± 6.0	44 ± 7.2	0.58	0.6859
	WMG	18 ± 3.2	13^{a} ± 1.4	10^{ab} ± 1.6	8^{ab} ± 1.2	6^{b} ± 1.0	5^{b} ± 1.7	5.39	0.0102
	BER	< 1 ± 0.38	< 1 ± 0.20	0	0	0	< 1 ± 0.10	1.50	0.2634
	Total	71 ± 3.5	60 ± 3.6	66 ± 4.8	51 ± 6.7	54 ± 7.4	53 ± 9.4	0.89	0.4985
Baylor Sandy									
30 Day	Absolute	99 ± 0.62	63 ± 4.5	68 ± 3.5	71 ± 3.6	58 ± 4.0	67 ± 5.4	1.27	0.3345
	WMG	2 ± 0.77	1 ± 0.20	1 ± 0.60	2 ± 1.0	1 ± 0.50	2 ± 0.90	0.76	0.5683
	BER	70 ± 12.4	< 1 ± 0.10	< 1 ± 0.30	< 1 ± 0.40	0	1 ± 0.50	0.68	0.6216
	Total	265 ± 42.7	74 ± 4.6	85 ± 4.5	92 ± 7.6	72 ± 6.0	86 ± 8.1	1.26	0.3398
60 Day	Absolute	95 ± 1.9	91 ± 2.6	91 ± 3.1	92 ± 2.8	92 ± 2.2	87 ± 2.7	0.59	0.6763
	WMG	2 ± 0.73	17^{a} ± 3.9	16^{a} ± 1.8	9^{ab} ± 1.1	9^{ab} ± 1.3	4^{b} ± 1.3	4.77	0.0155
	BER	78 ± 4.5	< 1 ± 0.30	1 ± 0.50	1 ± 1.0	< 1 ± 0.10	4 ± 1.8	1.83	0.1886
	Total	141 ± 7.07	153 ± 9.5	159 ± 10.7	156 ± 11.3	146 ± 6.3	136 ± 6.8	1.05	0.4226
90 Day	Absolute	41 ± 6.1	60 ± 6.9	68 ± 2.8	58 ± 5.8	52 ± 4.5	54 ± 7.5	2.38	0.1100
	WMG	4 ± 3.7	16^{a} ± 3.2	18^{a} ± 2.1	8^{b} ± 1.9	10^{ab} ± 1.7	2^{b} ± 1.0	11.67	0.0004
	BER	37 ± 5.0	0	1 ± 0.80	2 ± 1.6	0	5 ± 2.7	1.67	0.2200
	Total	43 ± 6.2	79 ± 11.2	89 ± 5.9	71 ± 8.0	71 ± 8.6	68 ± 11.9	2.11	0.1421
Clay									
30 Day	Absolute	99 ± 0.31	64 ± 6.4	60 ±5.9	61 ± 5.1	55 ± 1.9	62 ± 5.3	0.69	0.6140
	WMG	0	5 ± 1.6	3 ± 0.80	1 ± 0.30	1 ± 0.50	1 ± 0.30	3.58	0.0383**
	BER	14 ± 2.8	9 ± 3.0	10 ± 5.2	8 ± 3.9	8 ± 2.2	10 ± 4.9	0.32	0.8590
	Total	170 ± 5.3	74 ± 7.9	65 ± 6.6	66 ± 6.0	61 ± 3.4	70 ± 6.8	0.93	0.4785
60 Day	Absolute	100 ± 0.27	83 ± 1.8	86 ± 4.2	81 ± 4.5	82 ± 1.3	84 ± 3.9	0.44	0.7806
	WMG	0	6^{a} ± 1.6	4^{ab} ± 1.0	1^{b} ± 0.40	1^{b} ± 0.50	1^{b} ± 0.40	5.66	0.0085
	BER	29 ± 4.0	14 ± 3.7	14 ± 5.5	11 ± 4.4	13 ± 2.7	13 ± 5.2	0.19	0.9413
	Total	140 ± 4.4	108 ± 6.8	107 ± 6.8	102 ± 8.0	108 ± 2.4	106 ± 9.5	0.25	0.9047
90 Day	Absolute	83 ± 1.5	85 ± 2.4	80 ± 3.3	81 ± 4.0	86 ± 1.6	83 ± 2.6	1.58	0.2420
	WMG	0	9^{a} ± 2.2	4^{b} ± 1.2	1^{b} ± 0.50	1^{b} ± 0.50	1^{b} ± 0.30	18.45	< .0001

	BER	13 ± 4.1	11 ± 3.3	12 ± 5.0	9 ± 4.6	10 ± 2.8	13 ± 4.9	0.64	0.6469
	Total	113 ± 3.5	118 ± 6.8	111 ± 7.1	105 ± 8.6	114 ± 4.9	109 ± 4.8	2.39	0.1085
Kleberg Sandy									
30 Day	Absolute	90 ± 3.8	86 ± 4.1	88 ± 3.4	89 ± 5.0	81 ± 8.0	85 ± 4.8	0.55	0.7027
	WMG	1 ± 0.50	3 [a] ± 1.1	6 [a] ± 2.4	1[ab] ± 0.30	1[ab] ± 0.40	1[ab] ± 0.40	5.36	0.0104
	BER	67 ± 10.6	13 ± 3.9	14 ± 4.1	15 ± 3.7	15 ± 2.1	15 ± 3.4	0.12	0.9736
	Total	114 ± 8.5	118 ± 9.3	126 ± 10.1	120 ± 8.1	110 ± 11.5	119 ± 11.1	0.40	0.8052
60 Day	Absolute	90 ± 3.2	92 ± 2.9	97 ± 1.0	92 ± 2.5	93 ± 3.2	92 ± 4.6	0.36	0.8316
	WMG	< 1 ± 0.30	7[a] ± 2.4	12[a] ± 3.0	1[ab] ± 0.40	1[ab] ± 0.50	1[ab] ± 0.50	10.31	0.0007
	BER	65 ± 10.7	12 ± 3.3	12 ± 4.0	12 ± 3.4	14 ± 0.80	13 ± 2.7	0.11	0.9784
	Total	112 ± 10.2	130 ± 10.2	146 ± 8.3	113 ± 6.2	121 ± 4.1	118 ± 9.9	2.12	0.1416
90 Day	Absolute	99 ± 0.70	99 ± 0.50	99 ± 1.0	99 ± 0.40	91 ± 7.3	100 ± 0.30	1.18	0.3679
	WMG	6 ± 3.1	6[b] ± 1.3	11[a] ± 2.1	1[c] ± 0.70	1[c] ± 0.30	1[c] ± 0.30	23.41	< .0001
	BER	76 ± 9.2	14 ± 4.3	16 ± 4.7	17 ± 3.8	18 ± 3.4	19 ± 3.6	0.18	0.9454
	Total	145 ± 9.9	158 ± 10.3	167 ± 10.1	144 ± 6.4	145 ± 13.1	159 ± 10.7	1.16	0.3755
Clay									
30 Day	Absolute	94 ± 2.1	84 ± 4.0	78 ± 4.7	80 ± 4.7	80 ± 3.4	76 ± 5.2	0.69	0.6127
	WMG	4 ± 2.8	2 ± 1.0	3 ± 0.80	2 ± 1.4	1 ± 0.30	< 1 ± 0.20	1.26	0.3390
	BER	83 ± 5.9	24 ± 4.2	22 ± 4.2	21 ± 6.0	25 ± 4.3	19 ± 4.8	0.51	0.7328
	Total	121 ± 7.1	109 ± 7.0	110 ± 8.2	103 ± 8.9	108 ± 7.6	94 ± 7.9	0.75	0.5785
60 Day	Absolute	96 ± 1.8	91 ± 3.0	89 ± 2.5	87 ± 3.5	87 ± 3.9	87 ± 5.2	0.47	0.7552
	WMG	4 ± 2.9	5 ± 2.1	6 ± 2.1	3 ± 1.7	1 ± 0.50	1 ± 0.40	1.36	0.3062
	BER	87 ± 5.6	22 ± 4.8	23 ± 3.9	23 ± 5.8	28 ± 4.4	24 ± 4.5	0.71	0.6017
	Total	118 ± 6.2	121 ± 7.5	121 ± 8.2	107 ± 6.6	112 ± 7.5	112 ± 7.8	1.02	0.4345
90 Day	Absolute	99 ± 0.9	99 ± 0.80	99 ± 0.60	99 ± 0.40	100 ± 0	98 ± 1.0	1.57	0.2446
	WMG	4 ± 1.8	5 ± 3.2	5 ± 1.8	2 ± 1.0	2 ± 0.80	1 ± 0.30	0.87	0.5092
	BER	75 ± 7.2	28 ± 3.2	30 ± 5.4	25 ± 5.6	31 ± 3.4	26 ± 4.3	0.31	0.8647
	Total	152 ± 7.1	150 ± 7.4	159 ± 7.3	142 ± 6.4	158 ± 3.5	148 ± 6.1	2.04	0.1530

[1]Means followed by the same letter are not significantly different (Tukey-Kramer adjustment for multiple comparisons of least squares means, $P > 0.05$); reference plots were not included in the statistical analyses with the treatments.
[2]Absolute vegetation canopy cover (%) = 100 - bare ground (%) + rock (%) + litter (%); WMG indicates windmillgrass; 260 SS indicates shortspike WMG accession number 9085260; 283 SS indicates shortspike WMG accession number 9085283; 301 H indicates hooded WMG accession number 9085301; 313 H indicates hooded WMG accession number 9085313; BER indicates bermudagrass; Total indicates canopy cover including overlapping species.
*Treatment main effect was significant, but means were similar based on Tukey's test.
**TRT × SRB interaction.

Windmillgrass canopy cover was ≤ 1% in all locations, soils, and soil retention blanket treatments during 2006. The soil retention blanket's main effects in Andrews County for WMG were not significant ($P > 0.05$) at all evaluation dates. Applying soil retention blankets resulted in 35% less ($P = 0.0230$) absolute percent canopy cover of vegetation 30 days post-planting and 30% less ($P = 0.0245$) absolute percent canopy cover of vegetation 60 days post-planting in 2006 on sandy soil (Table 4-2-2). Use of soil retention blankets also resulted in 37% ($P = 0.0333$), and 35% ($P = 0.0244$) less total percent canopy cover at 30 and 60 day evaluations. The soil retention blanket's main effects were not significant ($P > 0.05$) in Baylor County during 2006 for absolute percent cover of vegetation, WMG, bermudagrass, and total percent canopy cover. Soil retention blanket's main effects in Kleberg County on sandy and clay soils were not significant ($P > 0.05$) for absolute percent cover of vegetation, WMG, and total percent canopy cover. Bermudagrass canopy cover was 67% less ($P = 0.0359$) with SRBs 30 days post-treatment on clay soil. During 2006, Baylor County provided at least 70% absolute canopy cover when compared to adjacent reference plots for both soil types and on all treatments; Kleberg County's sandy soil also provided at least 70% absolute canopy cover when compared to adjacent reference plots 30, 60, and 90 days post-treatment. In Andrews County, the SRB did not meet the 70% canopy cover requirement by 12%, 90 days post-treatment; the SRB treatment on Kleberg County's clay soil also did not meet the 70% canopy cover requirement by 26%, 90 days post-treatment.

Windmillgrass canopy cover was ≤ 12% in all locations, soils, and soil retention blanket treatments during 2007. Soil retention blanket's main effects were not significant ($P > 0.05$) in Andrews County for absolute percent cover of vegetation, bermudagrass, and total percent canopy cover (Table 4-2-2). Applying SRBs resulted in 28% greater ($P = 0.0375$) WMG canopy cover. Soil retention blanket's main effects were not significant ($P > 0.05$) in Baylor or Kleberg County for absolute percent cover of vegetation, WMG, bermudagrass, and total percent canopy cover. All locations, soils, and treatments during 2007 provided at least 70% absolute canopy cover when compared to adjacent reference plots.

Table 4-2-2. Mean (± SE) absolute percent canopy cover of vegetation, windmillgrass, bermudagrass, and total percent canopy cover for seeding treatments with and without the SRB treatment at Andrews, Baylor, and Kleberg Counties on sandy and clay soils during 2006-2007 at 30, 60, and 90 day evaluations.

2006		**Reference Plots**[1]	**SRB**[2]	**No SRB**	$F_{1,12}$	*P*
Andrews		% Canopy Cover (Mean ± SE)				
Sandy						
30 Day	Absolute[2]	84 ± 3.2	36 ± 2.7	55 ± 2.1	18.59	0.0230
	WMG[2]	21 ± 10.0	1 ± 0.20	1 ± 0.30	0.29	0.6301
	BER[2]	< 1 ± 0.50	0	< 1 ± 0.10	-	-
	Total[2]	109 ± 9.1	39 ± 3.4	62 ± 3.3	14.01	0.0333
60 Day	Absolute	79 ± 5.5	49 ± 2.5	70 ± 2.2	17.72	0.0245
	WMG	10 ± 7.8	1 ± 0.20	< 1 ± 0.10	5.77	0.0957
	BER	0	0	< 1 ± 0.10	-	-
	Total	87 ± 7.0	53 ± 3.2	82 ± 3.3	17.79	0.0244
90 Day	Absolute	67 ± 4.6	42 ± 2.2	53 ± 1.4	5.01	0.1110
	WMG	10 ± 5.4	1 ± 0.20	< 1 ± 0.10	6.15	0.0892

	BER	4 ± 1.7	0	< 1 ± 0.10	-	-
	Total	80 ± 6.3	43 ± 2.3	54 ± 1.4	4.72	0.1182
Baylor Sandy						
30 Day	Absolute	60 ± 5.5	53 ± 3.4	45 ± 2.6	1.53	0.3043
	WMG	0	0	0	-	-
	BER	49 ± 5.5	0	< 1 ± 0.20	-	-
	Total	79 ± 11.5	62 ± 4.5	51 ± 3.2	1.66	0.2877
60 Day	Absolute	12 ± 1.5	30 ± 2.0	19 ± 2.0	7.47	0.0717
	WMG	< 1 ± 0.25	0	< 1 ± 0.10	-	-
	BER	11 ± 1.5	0	< 1 ± 0.10	-	-
	Total	12 ± 1.5	31 ± 2.0	19 ± 2.0	7.06	0.0765
90 Day	Absolute	79 ± 4.9	69 ± 1.8	56 ± 2.9	2.96	0.1839
	WMG	6 ± 3.3	< 1 ± 0.10	< 1 ± 0.10	0.60	0.4950
	BER	59 ± 9.6	0	1 ± 0.40	-	-
	Total	91 ± 7.6	77 ± 2.5	64 ± 3.5	2.35	0.2229
Clay						
30 Day	Absolute	94 ± 1.0	18 ± 2.2	19 ± 3.1	1.27	0.3361
	WMG	0	0	0	0.99	0.3933
	BER	13 ± 6.0	1 ± 0.40	3 ± 1.1	0.02	0.8929
	Total	138 ± 7.0	19 ± 2.4	20 ± 3.4		
60 Day	Absolute	39 ± 4.4	55 ± 2.7	41 ± 4.0	2.47	0.1007
	WMG	0	< 1 ± 0.10	< 1 ± 0.20	0.86	0.4228
	BER	7 ± 5.2	3 ± 0.70	5 ± 1.8	0.59	0.4968
	Total	39 ± 4.6	63 ± 3.8	46 ± 4.6	5.58	0.0992
90 Day	Absolute	86 ± 2.1	92 ± 1.3	84 ± 2.8	1.62	0.2926
	WMG	0	1 ± 0.20	1 ± 0.50	0.18	0.6986
	BER	12 ± 7.0	6 ± 1.3	10 ± 2.9	0.43	0.5593
	Total	112 ± 3.1	136 ± 4.0	117 ± 7.3	2.45	0.2152
Kleberg Sandy						
30 Day	Absolute	79 ± 6.6	86 ± 2.9	66 ± 5.1	4.42	0.1264
	WMG	0	0	0	-	-
	BER	57 ± 10.8	10 ± 1.8	9 ± 1.7	0.40	0.5713
	Total	114 ± 21.7	129 ± 7.3	87 ± 9.1	2.29	0.2272
60 Day	Absolute	95 ± 1.7	96 ± 2.2	88 ± 4.5	3.26	0.1688*
	WMG	0	< 1 ± 0.20	1 ± 0.50	0.15	0.7251
	BER	60 ± 11.4	10 ± 2.2	10 ± 2.1	0.04	0.8597
	Total	178 ± 11.8	164 ± 9.8	136 ± 11.5	2.53	0.2096
90 Day	Absolute	63 ± 9.0	51 ± 6.0	61 ± 4.7	0.73	0.4566
	WMG	< 1 ± 0.25	< 1 ± 0.10	< 1 ± 0.10	0	1.0000
	BER	43 ± 14.7	5 ± 1.2	6 ± 1.4	0.63	0.4857

	Total	76 ± 13.7	59 ± 8.1	72 ± 7.2	0.49	0.5326
Clay						
30 Day	Absolute	80 ± 7.8	59 ± 4.2	58 ± 3.7	0.02	0.9102
	WMG	4 ± 3.1	0	0	-	-
	BER	54 ± 16.0	1 ± 0.40	3 ± 1.0	13.20	0.0359
	Total	103 ± 18.0	69 ± 4.9	70 ± 5.0	0	0.9557
60 Day	Absolute	89 ± 4.9	92 ± 2.0	96 ± 0.80	4.77	0.1169
	WMG	2 ± 2.3	0	0	-	-
	BER	59 ± 15.8	3 ± 0.90	7 ± 1.4	1.75	0.2778
	Total	124 ± 18.6	142 ± 5.7	151 ± 6.8	0.21	0.6814
90 Day	Absolute	55 ± 16.5	31 ± 5.8	44 ± 5.9	1.98	0.2539
	WMG	3 ± 1.2	0	< 1 ± 0.10	-	-
	BER	41 ± 18.8	2 ± 0.80	3 ± 1.3	0.26	0.6456
	Total	62 ± 20.1	37 ± 7.8	49 ± 8.0	1.60	0.2956
2007						
Andrews						
Sandy						
Final	Absolute	61 ± 2.3	48 ± 2.3	44 ± 3.8	0.14	0.7316
	WMG	18 ± 3.2	9 ± 1.0	7 ± 1.1	12.77	0.0375
	BER	< 1 ± 0.38	< 1 ± 0.10	< 1 ± 0.10	0.27	0.6376
	Total	71 ± 3.5	59 ± 3.2	54 ± 5.0	0.17	0.7076
Baylor						
Sandy						
30 Day	Absolute	99 ± 0.62	64 ± 2.7	67 ± 2.9	0.28	0.6339
	WMG	2 ± 0.77	2 ± 0.40	1 ± 0.50	0.11	0.7648
	BER	70 ± 12.4	< 1 ± 0.20	< 1 ± 0.20	3.00	0.1817
	Total	265 ± 42.7	82 ± 4.2	82 ± 4.2	0	1.0000
60 Day	Absolute	95 ± 1.9	90 ± 1.9	90 ± 1.5	0.01	0.9105
	WMG	2 ± 0.73	10 ± 1.4	1 ± 2.0	2.52	0.2106
	BER	78 ± 4.5	1 ± 0.70	2 ± 0.60	3.87	0.1438
	Total	141 ± 7.07	148 ± 5.5	152 ± 6.2	0.29	0.6269
90 Day	Absolute	41 ± 6.1	62 ± 4.1	54 ± 3.0	0.90	0.1100
	WMG	4 ± 3.7	12 ± 2.0	10 ± 1.6	0.39	0.5745
	BER	37 ± 5.0	1 ± 0.80	2 ± 1.1	1.32	0.2200
	Total	43 ± 6.2	83 ± 6.7	68 ± 4.4	1.16	0.3595
Clay						
30 Day	Absolute	99 ± 0.31	58 ± 3.0	63 ± 3.3	0.51	0.5275
	WMG	0	2 ± 0.60	2 ± 0.70	0.12	0.7519
	BER	14 ± 2.8	7 ± 1.3	12 ± 3.1	0.97	0.3963
	Total	170 ± 5.3	65 ± 3.6	70 ± 4.2	0.62	0.4898
60 Day	Absolute	100 ± 0.27	84 ± 1.9	82 ± 2.3	0.42	0.5628
	WMG	0	2 ± 0.50	3 ± 0.90	1.40	0.3213
	BER	29 ± 4.0	11 ± 1.7	15 ± 3.3	0.29	0.6298
	Total	140 ± 4.4	108 ± 4.0	104 ± 4.2	1.14	0.3640

90 Day	Absolute	83 ± 1.5	82 ± 1.8	84 ± 1.8	0.58	0.5033
	WMG	0	3 ± 1.1	3 ± 0.90	0.04	0.8573
	BER	13 ± 4.1	8 ± 1.5	14 ± 3.2	0.83	0.4296
	Total	113 ± 3.5	108 ± 4.0	114 ± 4.1	0.24	0.6552
Kleberg Sandy						
30 Day	Absolute	90 ± 3.8	93 ± 1.7	78 ± 3.6	3.34	0.1649
	WMG	1 ± 0.50	3 ± 1.1	2 ± 0.50	1.15	0.3627
	BER	67 ± 10.6	15 ± 2.4	14 ± 1.8	0.03	0.8756
	Total	114 ± 8.5	130 ± 5.0	107 ± 6.3	1.43	0.3170
60 Day	Absolute	90 ± 3.2	93 ± 2.3	94 ± 1.5	0.09	0.7785
	WMG	< 1 ± 0.30	5 ± 1.6	4 ± 1.3	0.07	0.8101
	BER	65 ± 10.7	12 ± 2.1	13 ± 1.6	0	0.9617
	Total	112 ± 10.2	125 ± 6.7	126 ± 4.2	0.01	0.9218
90 Day	Absolute	99 ± 0.70	100 ± 0.20	96 ± 3.0	2.13	0.2408
	WMG	6 ± 3.1	4 ± 1.2	4 ± 1.2	0	0.9785
	BER	76 ± 9.2	16 ± 2.6	18 ± 2.4	0.39	0.5756
	Total	145 ± 9.9	152 ± 7.6	156 ± 5.4	0.18	0.7012
Clay						
30 Day	Absolute	94 ± 2.1	77 ± 2.7	82 ± 2.7	0.22	0.6687
	WMG	4 ± 2.8	2 ± 0.60	2 ± 0.60	0.10	0.7697
	BER	83 ± 5.9	18 ± 3.0	26 ± 2.5	0.67	0.4734
	Total	121 ± 7.1	101 ± 4.7	109 ± 5.1	0.22	0.6717
60 Day	Absolute	96 ± 1.8	85 ± 2.8	91 ± 1.4	0.70	0.4636
	WMG	4 ± 2.9	2 ± 0.70	4 ± 1.3	1.48	0.3104
	BER	87 ± 5.6	19 ± 3.1	28 ± 2.4	0.87	0.4200
	Total	118 ± 6.2	106 ± 4.4	123 ± 4.2	1.94	0.2575
90 Day	Absolute	99 ± 0.9	99 ± 0.40	99 ± 0.40	0.01	0.9310
	WMG	4 ± 1.8	2 ± 0.60	3 ± 1.5	0.42	0.5612
	BER	75 ± 7.2	25 ± 3.2	31 ± 2.1	0.58	0.5005
	Total	152 ± 7.1	145 ± 4.1	158 ± 3.4	2.03	0.2497

[1]Reference plots were not included in the statistical analyses with the treatments.
[2]Absolute vegetation canopy cover (%) = 100 - bare ground (%) + rock (%) + litter (%); WMG indicates windmillgrass; BER indicates bermudagrass; Total indicates canopy cover including overlapping species; SRB indicates soil retention blanket.
*TRT × SRB interaction.

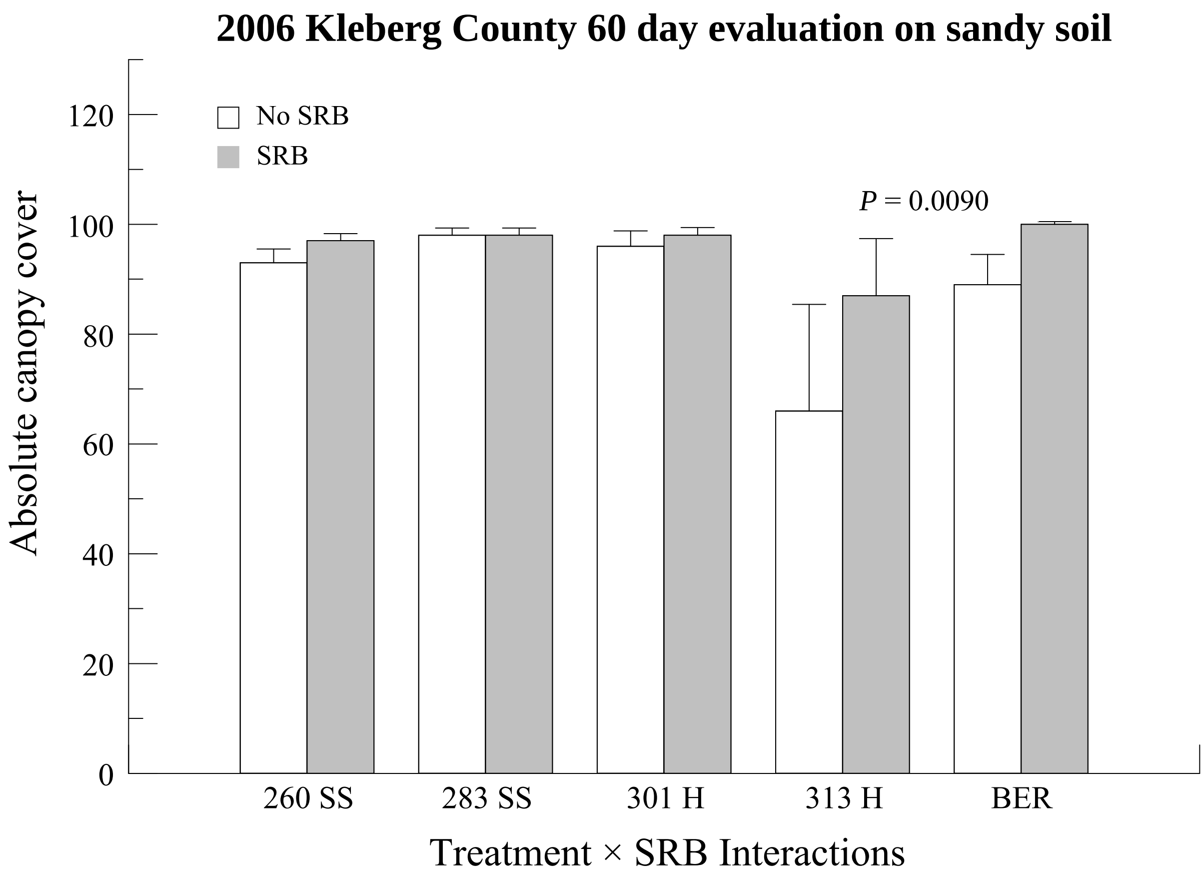

Figure 3-13. Treatment × SRB interactions during 2006 in Kleberg County on sandy soil 60 days post-treatment.

The mean (± SE) area (cm^2) of WMG occupying the sandy soil study site ranged from 267.5 ± 212.5 cm^2 within the shortspike (283) WMG plots to 1052.5 ± 872.5 cm^2 within the hooded (313) WMG plots (Table 4-2-3). The mean (± SE) area (cm^2) of WMG occupying the clay soil study site ranged from 112 ± 112.0 cm^2 within the hooded (301) WMG plots to 391 ± 201.0 cm^2 within the shortspike (283) WMG plots.

Table 4-2-3. Data from the mowing regimen was statistically analyzed for the mean (± SE) area (cm^2) occupied by randomly selected WMGs measured per treatment in Kleberg County during 2007.

	Mowing Regimen	
Kleberg county Treatments	**Sandy**	**Clay**
	(Mean ± SE)	
260 SS[1]	681 ± 177.0	265 ± 203.0
283 SS[1]	267.5 ± 212.5	391 ± 201.0
301 H[1]	332.3 ± 104.8	112 ± 112.0
313 H[1]	1052.5 ± 872.5	186 ± 30.0

[1]260 SS indicates shortspike WMG accession number 9085260; 283 SS indicates shortspike WMG accession number 9085283; 301 H indicates hooded WMG accession number 9085301; 313 H indicates hooded WMG accession number 9085313; BER indicates bermudagrass.

4.3 Native Alternatives to Introduced Species

Windmillgrass canopy cover was ≤ 7% in all locations, soils, and treatments during 2006. Treatment main effects were not significant ($P > 0.05$) in Andrews, Baylor, and Kleberg Counties during 2006 for absolute percent cover of vegetation, WMG, bermudagrass, and total percent canopy cover (Table 4-3-1). During 2006, Baylor County provided at least 70% absolute canopy cover when compared to adjacent reference plots for both soil types and on all treatments. Absolute canopy cover on sandy soil in Kleberg County was ≥ 70% when compared to adjacent reference plots 30, 60, and 90 days post-treatment. In Andrews County, 260 SS WMG did not meet the 70% canopy cover requirement by 12%, 90 days post-treatment. In Kleberg County on clay soil accessions 301 H WMG and 313 H WMG, and bermudagrass did not meet the 70% canopy cover requirement by 15%, 18%, and 34%, respectively, 90 days post-treatment.

Windmillgrass canopy cover was ≤ 34% in all locations, soils, and treatments during 2007. Treatment main effects were not significant ($P > 0.05$) in Andrews County for absolute percent cover of vegetation, WMG, bermudagrass, and total percent canopy cover (Table 4-3-1). Canopy cover of windmillgrass was greater ($P < 0.05$) of accessions 260 SS WMG, 283 SS WMG, 301 H WMG, and 313 H WMG than bermudagrass 60 and 90 days after planting on sandy and clay soils in Baylor County; absolute percent vegetation canopy cover and total vegetation canopy cover were similar ($P > 0.05$) among treatments 30, 60, and 90 days post-planting. Absolute canopy cover of accession 260 SS WMG was 28% greater ($P = 0.0184$) than bermudagrass on sandy soil 30 days post-planting in Kleberg County; however, WMG canopy cover, bermudagrass canopy cover, and total percent canopy cover were similar ($P > 0.05$) among treatments.

Treatment main effects were not significant ($P > 0.05$) in Kleberg County during 2007 on sandy soil for absolute percent canopy cover of vegetation, WMG, bermudagrass, and total canopy cover 60 days post-planting. Total canopy cover of accession 260 SS WMG was 8% greater ($P = 0.0002$) than bermudagrass canopy cover on sandy soil 90 days post-planting in Kleberg County; however, absolute percent vegetation canopy cover, WMG canopy cover, and bermudagrass canopy cover were similar ($P > 0.05$) among treatments. Treatment main effects were not significant ($P > 0.05$) in Kleberg County on clay soil for absolute percent cover of vegetation, WMG, bermudagrass, and total percent canopy cover 30 and 90 days post-treatment; however, WMG canopy cover was 300-900% greater ($P < 0.05$) for all WMG treatments than in the bermudagrass treatment 60 days post-planting. Total canopy cover of accession 260 SS WMG was 15% greater ($P = 0.0113$) than bermudagrass canopy cover on clay soil 60 days post-planting in Kleberg County. All locations, soils, and treatments during 2007 provided at least 70% absolute canopy cover when compared to adjacent reference plots.

Table 4-3-1. Mean (± SE) absolute percent canopy cover of vegetation, windmillgrass, bermudagrass, and total percent canopy cover for each treatment at Andrews, Baylor, and Kleberg Counties on sandy and clay soils during 2006-2007 at 30, 60, and 90 day evaluations.

2006		Reference Plots[1]	260 SS[2]	283 SS[2]	301 H[2]	313 H[2]	BER[2]	$F_{4,12}$	*P*
		% Canopy Cover (Mean ± SE)							
Andrews									
Sandy									
30 Day	Absolute[2]	84 ± 3.2	62 ± 3.7	51 ± 4.5	55 ± 2.6	52 ± 4.8	60 ± 7.3	1.08	0.4091
	WMG[2]	21 ± 10.0	7 ± 2.8	5 ± 1.2	6 ± 1.7	7 ± 2.6	1 ± 0.58	1.65	0.2256
	BER[2]	< 1 ± 0.50	0	0	2 ± 1.8	2 ± 0.87	2 ± 1.4	0.83	0.5334
	Total[2]	109 ± 9.1	70 ± 4.9	60 ± 6.5	62 ± 4.9	61 ± 6.6	66 ± 10.0	0.38	0.8194
60 Day	Absolute	79 ± 5.5	68 ± 2.5	66 ± 5.7	67 ± 4.5	64 ± 6.6	69 ± 4.0	0.51	0.7303
	WMG	10 ± 7.8	1 ± 0.75	6 ± 1.8	3 ± 1.7	6 ± 3.0	1 ± 0.48	2.94	0.0661
	BER	0	1 ± 0.50	0	0	0	< 1 ± 0.25	1.00	0.4449
	Total	87 ± 7.0	78 ± 2.5	77 ± 10.8	78 ± 5.3	75 ± 7.5	80 ± 7.0	0.17	0.9512
90 Day	Absolute	67 ± 4.6	42 ± 1.9	46 ± 3.4	44 ± 3.4	45 ± 3.8	47 ± 4.8	1.11	0.3954
	WMG	10 ± 5.4	3 ± 0.71	2 ± 0.0	2 ± 0.71	2 ± 0.29	3 ± 0.65	1.95	0.1667
	BER	4 ± 1.7	0	0	0	0	0	-	-
	Total	80 ± 6.3	52 ± 3.8	53 ± 4.1	54 ± 4.0	54 ± 5.0	59 ± 7.4	0.93	0.4783
Baylor									
Sandy									
30 Day	Absolute	60 ± 5.5	64 ± 6.7	69 ± 8.0	71 ± 7.2	63 ± 9.9	57 ± 5.8	2.75	0.0783
	WMG	0	0	0	0	0	0	-	-
	BER	49 ± 5.5	17 ± 8.8	2 ± 1.4	14 ± 8.2	10 ± 4.7	2 ± 0.75	1.47	0.2709
	Total	79 ± 11.5	81 ± 15.3	83 ± 11.3	89 ± 12.1	79 ± 16.5	65 ± 9.1	1.53	0.2561
60 Day	Absolute	12 ± 1.5	38 ± 7.3	28 ± 5.3	32 ± 6.7	27 ± 5.7	22 ± 2.5	1.75	0.2030
	WMG	< 1 ± 0.25	< 1 ± 0.25	0	0	0	0	1.00	0.4449
	BER	11 ± 1.5	18 ± 8.5	2 ± 0.82	14 ± 8.0	9 ± 4.9	2 ± 0.65	1.83	0.1882
	Total	12 ± 1.5	40 ± 8.4	29 ± 5.8	33 ± 7.6	30 ± 7.8	22 ± 2.5	1.58	0.2423
90 Day	Absolute	79 ± 4.9	78 ± 5.2	73 ± 6.1	75 ± 2.8	72 ± 3.4	67 ± 1.9	1.62	0.2320
	WMG	6 ± 3.3	1 ± 0.48	0	0	< 1 ± 0.25	< 1 ± 0.25	1.55	0.2496
	BER	59 ± 9.6	33 ± 11.8	4 ± 1.5	19 ± 11.3	17 ± 8.9	4 ± 1.5	2.38	0.1096
	Total	91 ± 7.6	99 ±9.9	88 ± 10.3	91 ± 5.3	88 ± 10.9	76 ± 4.5	2.11	0.1429
Clay									
30 Day	Absolute	94 ± 1.0	18 ± 7.9	17 ± 5.4	10 ± 2.1	28 ± 8.3	22 ± 9.4	1.06	0.4184

	WMG	0	0	0	0	0	< 1 ± 0.25	1.00	0.4449
	BER	13 ± 6.0	10 ± 5.8	10 ± 4.1	3 ± 1.1	9 ± 2.6	6 ± 3.9	0.58	0.6818
	Total	138 ± 7.0	20 ± 8.5	19 ± 6.2	10 ±2.1	31 ± 9.6	25 ± 11.6	1.09	0.4052
60 Day	Absolute	39 ± 4.4	32 ± 13.4	29 ± 5.5	26 ± 6.7	45 ± 11.3	34 ± 11.7	0.83	0.5323
	WMG	0	1 ± 0.75	1 ± 0.29	< 1 ± 0.25	< 1 ± 0.25	< 1 ± 0.25	1.22	0.3544
	BER	7 ± 5.2	17 ± 10.2	13 ± 3.8	3 ± 1.7	14 ± 5.0	6 ± 4.6	0.94	0.4751
	Total	39 ± 4.6	36 ±15.1	34 ± 6.9	28 ± 7.2	53 ± 15.2	38 ± 15.2	0.82	0.5393
90 Day	Absolute	86 ± 2.1	79 ± 14.2	83 ± 4.0	86 ± 5.4	89 ± 7.3	85 ± 5.1	0.46	0.7662
	WMG	0	5 ± 2.3	2 ± 0.85	2 ± 1.1	2 ± 1.8	1 ± 0.29	1.66	0.2242
	BER	12 ± 7.0	31 ± 16.6	30 ± 10.7	14 ± 1.9	25 ± 5.1	17 ±6.4	0.55	0.7034
	Total	112 ± 3.1	124 ± 31.8	127 ± 12.0	114 ± 10.2	134 ± 16.6	123 ± 16.3	0.32	0.8603
Kleberg Sandy									
30 Day	Absolute	79 ± 6.6	36 ± 7.4	14 ± 4.2	33 ± 7.4	34 ± 8.7	31 ± 8.5	1.44	0.2806
	WMG	0	0	0	0	0	0	-	-
	BER	57 ± 10.8	19 ± 5.0	5 ± 3.2	12 ± 3.9	13 ± 5.8	14 ± 4.1	2.10	0.1437
	Total	114 ± 21.7	41 ± 10.0	16 ± 5.2	36 ± 8.1	39 ± 10.2	33 ± 9.6	1.32	0.3190
60 Day	Absolute	95 ± 1.7	91 ± 5.1	65 ± 5.0	84 ± 5.6	80 ± 8.9	84 ± 8.0	1.91	0.1736
	WMG	0	0	0	0	0	0	-	-
	BER	60 ± 11.4	43 ± 5.5	16 ± 8.2	31 ± 5.7	28 ± 9.3	35 ± 11.1	3.01	0.0622
	Total	178 ± 11.8	155 ± 20.4	86 ± 8.8	142 ± 19.8	117 ± 16.8	127 ± 16.9	2.29	0.1200
90 Day	Absolute	63 ± 9.0	66 ± 6.0	51 ± 8.9	59 ± 1.2	62 ± 4.6	59 ± 7.9	0.72	0.5958
	WMG	< 1 ± 0.25	0	< 1 ± 0.25	0	< 1 ± 0.25	0	0.69	0.6114
	BER	43 ± 14.7	25 ± 5.3	11 ± 5.9	17 ± 7.7	20 ± 7.7	26 ± 11.2	1.29	0.3287
	Total	76 ± 13.7	80 ± 10.7	55 ± 11.9	70 ± 4.1	70 ± 6.7	65 ± 9.9	0.87	0.5079
Clay									
30 Day	Absolute	80 ± 7.8	39 ± 12.1	26 ± 8.0	29 ± 4.2	32 ± 6.8	20 ± 2.5	1.91	0.1740
	WMG	4 ± 3.1	0	0	0	0	< 1 ± 0.25	1.00	0.4449
	BER	54 ± 16.0	14 ± 2.4	13 ± 7.6	11 ± 2.1	13 ± 3.3	7 ± 2.1	0.69	0.6124
	Total	103 ± 18.0	49 ± 18.4	30 ± 10.9	33 ± 5.8	35 ± 8.2	22 ± 3.1	1.84	0.1868
60 Day	Absolute	89 ± 4.9	95 ± 2.3	94 ± 3.9	96 ± 1.3	94 ± 1.3	88 ± 3.0	1.26	0.3373
	WMG	2 ± 2.3	2 ±1.5	< 1 ± 0.25	0	0	0	1.00	0.4449
	BER	59 ± 15.8	49 ± 5.3	53 ± 6.8	41 ± 6.7	55 ± 7.4	29 ± 4.2	3.10	0.0573
	Total	124 ± 18.6	195 ± 17.8	190 ± 23.3	168 ± 13.7	184 ± 13.5	140 ± 7.9	1.91	0.1736

90 Day	Absolute	55 ± 16.5	46 ± 12.3	47 ± 9.8	34 ± 6.0	33 ± 1.8	29 ± 3.4	1.23	0.3499
	WMG	3 ± 1.2	2 ± 1.2	< 1 ± 0.25	< 1 ± 0.25	0	0	2.23	0.1267
	BER	41 ± 18.8	11 ± 4.8	18 ± 3.8	10 ± 4.2	12 ± 3.0	7 ± 2.5	1.24	0.3452
	Total	62 ± 20.1	54 ± 17.6	52 ± 12.1	37 ± 7.6	35 ± 2.8	30 ± 3.8	1.14	0.3823
2007									
Andrews									
Sandy									
Final	Absolute	61 ± 2.3	62 ± 5.8	57 ± 6.1	54 ± 6.9	61 ± 5.6	57 ± 7.4	1.60	0.2380
	WMG	18 ± 3.2	34 ± 7.7	29 ± 1.8	29 ± 5.0	32 ± 6.9	19 ± 5.1	1.66	0.2237
	BER	< 1 ± 0.38	0	0	0	0	< 1 ± 0.25	1.00	0.4449
	Total	71 ± 3.5	80 ± 10.4	77 ± 9.7	70 ± 10.8	81 ± 10.5	69 ± 9.6	1.83	0.1873
Baylor									
Sandy									
30 Day	Absolute	99 ± 0.62	77 ± 6.3	68 ± 5.6	74 ± 6.0	72 ± 3.9	70 ± 5.3	0.62	0.6542
	WMG	2 ± 0.77	3 ± 1.8	< 1 ± 0.25	1 ± 0.50	2 ± 1.4	1 ± 0.41	1.07	0.4120
	BER	70 ± 12.4	32 ± 10.6	6 ± 2.5	26 ± 15.4	20 ± 8.1	10 ± 3.7	1.50	0.2623
	Total	265 ± 42.7	116 ± 14.9	93 ± 11.0	105 ± 14.0	103 ± 9.9	91 ± 12.0	1.38	0.2983
60 Day	Absolute	95 ± 1.9	78 ± 3.8	90 ± 4.8	83 ± 7.3	81 ± 6.1	84 ± 4.4	0.81	0.5435
	WMG	2 ± 0.73	11^{a} ± 3.6	12^{a} ± 4.2	5^{ab} ± 1.6	8^{ab} ± 3.1	2^{b} ± 0.29	4.32	0.0215
	BER	78 ± 4.5	39 ± 14.6	15 ± 4.8	29 ± 17.9	28 ± 9.7	16 ± 6.3	0.81	0.5442
	Total	141 ± 7.07	146 ± 12.9	156 ± 9.4	153 ± 12.3	150 ± 13.7	139 ± 10.0	0.53	0.7146
90 Day	Absolute	41 ± 6.1	73 ± 4.3	64 ± 3.9	58 ± 7.9	67 ± 7.3	63 ± 3.7	1.32	0.3177
	WMG	4 ± 3.7	17 ± 5.6	20 ± 6.9	5 ± 1.3	10 ± 4.5	3 ± 1.9	3.66	0.0359*
	BER	37 ± 5.0	50 ± 6.9	18 ± 5.1	30 ± 18.2	35 ± 11.7	27 ± 9.8	1.11	0.3963
	Total	43 ± 6.2	96 ± 7.1	88 ± 7.3	69 ± 10.2	90 ± 13.9	79 ± 5.0	2.28	0.1208
Clay									
30 Day	Absolute	99 ± 0.31	58 ± 13.1	65 ± 6.0	52 ± 4.0	55 ± 9.5	49 ± 7.0	0.74	0.5853
	WMG	0	11 ± 4.8	8 ± 2.2	5 ± 1.4	3 ± 2.8	3 ± 1.3	1.84	0.1852
	BER	14 ± 2.8	32 ± 17.7	42 ± 8.0	26 ± 3.2	31 ± 9.2	15 ± 5.8	0.91	0.4881
	Total	170 ± 5.3	71 ± 19.2	77 ± 9.9	58 ± 4.7	64 ± 12.0	55 ± 8.5	0.70	0.6039
60 Day	Absolute	100 ± 0.27	91 ± 4.5	92 ± 0.85	85 ± 3.8	88 ± 5.2	84 ± 2.4	2.06	0.1502
	WMG	0	19^{a} ± 2.1	12^{ab} ± 4.2	6^{b} ± 2.1	5^{b} ± 2.6	3^{b} ± 1.4	6.81	0.0042
	BER	29 ± 4.0	39 ± 19.1	51 ± 7.7	40 ± 3.7	49 ± 9.3	20 ± 6.3	1.41	0.2895
	Total	140 ± 4.4	118 ± 11.3	125 ± 6.7	109 ± 7.5	113 ± 12.7	109 ± 5.0	1.17	0.3734
90 Day	Absolute	83 ± 1.5	86 ± 2.6	83 ± 1.8	84 ± 1.1	87 ± 1.8	84 ± 1.6	0.80	0.5485
	WMG	0	21^{a} ± 2.5	12^{ab} ± 2.3	7^{b} ± 2.2	7^{b} ± 3.3	4^{b} ± 0.95	8.84	0.0015

	BER	13 ± 4.1	36 ± 18.6	50 ± 12.0	39 ± 3.1	47 ± 9.5	25 ± 8.5	0.68	0.6164
	Total	113 ± 3.5	124 ± 3.9	117 ± 4.4	123 ± 4.9	126 ± 2.3	122 ± 5.1	0.79	0.5516
Kleberg Sandy									
30 Day	Absolute	90 ± 3.8	72^{a} ± 10.0	43^{b} ± 6.3	61^{ab} ± 8.8	55^{ab} ± 1.6	56^{ab} ± 4.9	4.53	0.0184
	WMG	1 ± 0.50	7 ± 2.6	9 ± 4.2	3 ± 1.5	4 ± 3.0	4 ± 2.0	0.71	0.6021
	BER	67 ± 10.6	54 ± 8.0	17 ± 7.2	38 ± 12.6	34 ± 5.1	34 ± 9.0	2.66	0.0850
	Total	114 ± 8.5	85 ± 9.5	54 ± 9.9	78 ± 15.0	68 ± 2.7	65 ± 6.1	2.39	0.1092
60 Day	Absolute	90 ± 3.2	91 ± 3.8	84 ± 3.5	93 ± 2.6	96 ± 1.8	89 ± 5.1	2.62	0.0881
	WMG	< 1 ± 0.30	20 ± 6.8	20 ± 8.5	11 ± 3.3	12 ± 4.6	9 ± 3.5	1.07	0.4140
	BER	65 ± 10.7	52 ± 6.8	22 ± 7.1	42 ± 9.3	33 ± 9.7	40 ± 10.6	2.07	0.1488
	Total	112 ± 10.2	133 ± 12.9	110 ± 6.7	134 ± 8.4	139 ± 6.8	125 ± 12.1	1.48	0.2683
90 Day	Absolute	99 ± 0.70	99 ± 1.0	99 ± 0.65	99 ± 1.0	100 ± 0.25	100 ± 0.29	0.67	0.6248
	WMG	6 ± 3.1	23 ± 2.2	15 ± 3.2	23 ± 11.7	14 ± 6.7	8 ± 4.1	0.95	0.4694
	BER	76 ± 9.2	44 ± 15.4	12 ± 5.0	23 ± 13.3	23 ± 6.3	31 ± 10.7	1.74	0.2048
	Total	145 ± 9.9	183^{ab} ± 8.8	158^{c} ± 5.5	165^{c} ± 6.6	192^{a} ± 8.5	169^{bc} ± 6.2	13.87	0.0002
Clay									
30 Day	Absolute	94 ± 2.1	78 ± 4.5	83 ± 2.8	79 ± 5.6	80 ± 3.2	74 ± 7.6	0.46	0.7662
	WMG	4 ± 2.8	11 ± 6.1	3 ± 1.8	0	< 1 ± 0.25	0	2.88	0.0692
	BER	83 ± 5.9	53 ± 5.0	58 ± 10.5	52 ± 11.6	57 ± 5.2	49 ± 6.8	0.21	0.9299
	Total	121 ± 7.1	102 ± 8.8	105 ± 8.0	103 ± 10.8	105 ± 4.7	95 ± 12.6	0.26	0.8966
60 Day	Absolute	96 ± 1.8	97 ± 1.3	96 ± 2.3	93 ± 2.4	95 ± 0.95	93 ± 2.7	1.01	0.4417
	WMG	4 ± 2.9	20^{a} ± 6.6	8^{ab} ± 4.6	1^{b} ± 0.25	1^{b} ± 0.50	2^{b} ± 1.1	5.35	0.0104
	BER	87 ± 5.6	67 ± 3.2	61 ± 10.1	65 ± 8.1	79 ± 2.1	57 ± 1.8	2.16	0.1354
	Total	118 ± 6.2	152^{a} ± 6.7	127^{b} ± 6.8	134^{ab} ± 3.8	133^{b} ± 5.1	132^{b} ± 6.8	5.23	0.0113
90 Day	Absolute	99 ± 0.9	100 ± 0.0	100 ± 0.25	99 ± 0.75	100 ± 0.0	100 ± 0.50	0.54	0.7116
	WMG	4 ± 1.8	8 ± 7.5	4 ± 2.4	3 ± 1.3	2 ± 1.2	2 ± 1.1	0.47	0.7562
	BER	75 ± 7.2	62 ± 5.7	70 ± 7.9	63 ± 10.3	77 ± 10.0	61 ± 4.5	1.02	0.4344
	Total	152 ± 7.1	169 ± 4.5	176 ± 4.4	158 ± 5.4	169 ± 5.5	162 ± 6.8	1.96	0.1643

[1]Means followed by the same letter are not significantly different (Tukey-Kramer adjustment for multiple comparisons of least squares means, $P >$ 0.05); reference plots were not included in the statistical analyses with the treatments.

[2]Absolute vegetation canopy cover (%) = 100 - bare ground (%) + rock (%) + litter (%); WMG indicates windmillgrass; 260 SS indicates shortspike WMG accession number 9085260; 283 SS indicates shortspike WMG accession number 9085283; 301 H indicates hooded WMG accession number 9085301; 313 H indicates hooded WMG accession number 9085313; BER indicates bermudagrass; Total indicates canopy cover including overlapping species.

*Treatment main effect was significant, but means were similar based on Tukey's test.

Mean (± SE) area (cm^2) of WMG occupying the sandy soil study site ranged from 282.5 ± 107.5 cm^2 within the hooded (301) WMG plots to 720 ± 680.0 cm^2 within the hooded (313) WMG plots (Table 4-3-2). The mean (± SE) area (cm^2) of WMG occupying the clay soil study site ranged from 328.8 ± 248.8 cm^2 within the shortspike (283) WMG plots to 1108 ± 548.0 cm^2 within the shortspike (260) WMG plots.

Table 4-3-2. Data from the mowing regimen was statistically analyzed for mean (± SE) area (cm^2) occupied by randomly selected WMGs measured per treatment in Kleberg County during 2007.

Mowing Regimen		
Kleberg county		
	Sandy	**Clay**
Treatments	**Mean ± SE**	
260 SS[1]	293.5 ± 14.5	1108 ± 548.0
283 SS[1]	401 ± 17.0	328.8 ± 248.8
301 H[1]	282.5 ± 107.5	500.5 ± 60.5
313 H[1]	720 ± 680.0	387 ± 338.0

[1]260 SS indicates shortspike WMG accession number 9085260; 283 SS indicates shortspike WMG accession number 9085283; 301 H indicates hooded WMG accession number 9085301; 313 H indicates hooded WMG accession number 9085313; BER indicates bermudagrass.

4.4 Assessment of Two Commonly Used Seeding Techniques

Windmillgrass canopy cover was ≤ 3% for both soil types and treatments during 2006 in Kleberg County. Treatment main effects were not significant for absolute canopy cover of vegetation, WMG, and total percent canopy cover ($P > 0.05$) on sandy soils; however, canopy cover of bermudagrass was greater ($P < 0.05$) in plots hand broadcasted 30, 60, and 90 days post-planting (Table 4-4). Treatment main effects were not significant for WMG, bermudagrass, and total percent canopy cover ($P > 0.05$) on clay soils; however, absolute percent canopy cover was 58% greater ($P = 0.0480$) in plots drilled 30 days post-planting, and 12% greater ($P = 0.0428$) 90 days post-planting. Broadcasting seeds on sandy soil did provide at least 70% absolute canopy cover of the adjacent reference plots 90 days post-planting, but canopy cover on drilled plots was 11% lower than the required canopy cover. Both seeding techniques on the clay soil provided at least 70% absolute canopy cover compared to adjacent plots.

Table 4-4. Mean (± SE) absolute percent canopy cover of vegetation, windmillgrass, bermudagrass, and total percent canopy cover for each treatment at Kleberg County on sandy and clay soils during 2006 at 30, 60, and 90 day evaluations.

			Reference Plots[1]	Drill	Broadcast	$F_{1,3}$	*P*
Kleberg			% Canopy Cover (Mean ± SE)				
Sandy							
	30 Day	Absolute[2]	79 ± 6.6	30 ± 12.4	41 ± 4.3	1.04	0.3831
		WMG[2]	0	0	0	-	-
		BER[2]	57 ± 10.8	6 ± 1.9	19 ± 3.7	15.87	0.0283
		Total[2]	114 ± 21.7	42 ± 16.8	48 ± 8.3	0.22	0.6705
	60 Day	Absolute	95 ± 1.7	67 ± 17.6	90 ± 4.3	2.62	0.2039
		WMG	0	< 1 ± 0.25	0	1.00	0.3910
		BER	60 ± 11.4	9 ± 0.41	39 ± 8.1	14.40	0.0321
		Total	178 ± 11.8	104 ± 33.2	143 ± 14.9	3.59	0.1542
	90 Day	Absolute	63 ± 9.0	33 ± 10.1	49 ± 2.9	4.14	0.1347
		WMG	< 1 ± 0.25	0	0	-	-
		BER	43 ± 14.7	4 ± 1.5	17 ± 3.3	23.02	0.0172
		Total	75 ± 13.7	34 ± 9.9	52 ± 3.3	5.63	0.0983
Clay							
	30 Day	Absolute	80 ± 7.8	49 ± 6.0	31 ± 3.8	11.94	0.0480
		WMG	4 ± 3.1	0	0	-	-
		BER	54 ± 16.0	31 ± 5.5	17 ± 2.5	9.56	0.0536
		Total	103 ± 18.0	54 ± 8.4	37 ± 6.2	3.24	0.1698
	60 Day	Absolute	89 ± 4.9	67 ± 4.7	81 ± 4.7	10.09	0.0502
		WMG	2 ± 2.3	1 ± 1.0	3 ± 2.8	1.00	0.3910
		BER	59 ± 159.8	40 ± 7.6	50 ± 4.4	6.21	0.0883
		Total	124 ± 18.6	87 ± 12.3	113 ± 7.9	5.11	0.1089
	90 Day	Absolute	55 ± 16.5	76 ± 1.5	68 ± 2.6	11.49	0.0428
		WMG	3 ± 1.2	0	0	-	-
		BER	41 ± 18.8	0	< 1 ± 0.50	1.00	0.3910
		Total	62 ± 20.1	130 ± 34.3	133 ± 34.6	1.20	0.3539

[1]Reference plots were not included in the statistical analysis with the treatments.
[2]Absolute vegetation canopy cover (%) = 100 - bare ground (%) + rock (%) + litter (%); WMG indicates windmillgrass; BER indicates bermudagrass; Total indicates canopy cover including overlapping species.

4.5 Supplemental Irrigation

Water volume means for treatments in the native seed mixture experiment ranged from 19 ± 3.0 mL to 27.8 ± 1.4 mL on sandy soil and 21 ± 4.6 mL to 30.8 ± 6.5 mL on clay soils (Table 4-5). Water volume treatment means for the SRB experiment ranged from 52.3 ± 4.4 mL to 59.8 ± 7.8 mL on sandy soil and 43.8 ± 5.4 mL to 66.8 ± 13.0 mL on clay soil. Water volume means for treatments in the monoculture experimental plots ranged from 119.5 ± 14.4 mL to 128.3 ± 8.1 mL on sandy soil and 77.5 ± 11.5 mL to 97 ± 5.6 mL on clay soil. Water volume treatment means for the seeding techniques experiment ranged from 103.3 ± 4.6 mL to 103.3 ± 13.0 mL on sandy soil and 116.3 ± 17.5 mL to 129 ± 16.7 mL on clay soil.

Table 4-5. Data from the supplemental irrigation was statistically analyzed for the mean (± SE) volume (mL) applied to experiments per treatment in Kleberg County during 2006.

	Supplemental Irrigation	
Kleberg county	**Sandy**	**Clay**
Exp. 1[1]	Mean ± SE	
Standard	19 ± 3.0	26.3 ± 6.2
Native	27 ± 3.0	30.8 ± 6.5
Combination	27.8 ± 1.4	21 ± 4.6
Exp. 2[1]		
260 SS[2]	53.8 ± 3.0	43.8 ± 5.4
283 SS[2]	52.3 ± 4.4	58 ± 10.4
301 H[2]	59.8 ± 7.8	58.5 ± 5.9
313 H[2]	54.5 ± 9.6	66.8 ± 13.0
BER[2]	55.3 ± 8.8	53.3 ± 12.6
Exp. 3[1]		
260 SS	124.3 ± 3.9	84.8 ± 3.6
283 SS	125.3 ± 5.3	83.5 ± 32.4
301 H	128.3 ± 8.1	77.5 ± 11.5
313 H	122.5 ± 9.7	97 ± 5.6
BER	119.5 ± 14.4	90.3 ± 29.9
Exp. 4[1]		
Drill	103.3 ± 13.0	129 ± 16.7
Broadcast	103.3 ± 4.6	116.3 ± 17.5

[1]Exp. 1 indicates samples from Revegetating Right of Ways with Native Seed Mixtures experiment; Exp. 2 indicates samples from Establishing Roadside Vegetation with Soil Retention Blankets experiment; Exp. 3 indicates samples from Replacing Bermudagrass with Native Windmillgrasses experiment; Exp. 4 indicates samples from Assessment of Two Commonly Used Seeding Techniques experiment; RP indicates samples from reference plots. Measured in mL.
[2]260 SS indicates shortspike WMG accession number 9085260; 283 SS indicates shortspike WMG accession number 9085283; 301 H indicates hooded WMG accession number 9085301; 313 H indicates hooded WMG accession number 9085313; BER indicates bermudagrass.

4.6 Soil Samples

In Andrews County, pH for all experiments and reference plots was slightly alkaline to moderately alkaline (Table 4-6). Conductivity ranged from 157 ± 8.2 umol/cm to 225 ± 45.7 umol/cm. Nitrate-nitrogen was extremely low for all experiments. Levels of phosphorus were very low to low. Levels of potassium were high to very high for all experiments and reference plots. Calcium, magnesium, and sulfur levels were high at all experiments and reference plots, while sodium was low.

In Baylor County on sandy soil, pH for all experiments and reference plots was slightly alkaline (Table 4-6). Conductivity ranged from 139.5 ± 9.3 umol/cm to 198.3 ± 14.3 umol/cm.

Nitrate-nitrogen was extremely low and phosphorus was moderate for all experiments. Potassium was very high for all experiments and reference plots. Calcium, magnesium, and sulfur levels were high at all experiments and reference plots, while sodium was low.

In Baylor County on clay soil, pH for all experiments and reference plots was slightly alkaline to moderately alkaline (Table 4-6). Conductivity ranged from 273.5 ± 55.3 umol/cm to 338.3 ± 10.3 umol/cm. Nitrate-nitrogen was extremely low and phosphorus was very low. Potassium was high to very high for all experiments and reference plots. Calcium, magnesium, and sulfur were high to very high at all experiments and reference plots, while sodium was low.

In Kleberg County on sandy soil, pH for all experiments and reference plots was moderately alkaline (Table 4-6). Conductivity ranged from 296 ±6.1 umol/cm to 343.8 ± 9.5 umol/cm. Nitrate-nitrogen was low for all experiments and phosphorus was deemed low. Potassium and calcium was very high for all experiments and reference plots. Magnesium and sulfur was high to very high. Sodium levels were low.

In Kleberg County on clay soil, pH for all experiments and reference plots was slightly to moderately alkaline (Table 4-6). Conductivity ranged from 303.5 ± 1.4 umol/cm to 343 ± 7.0 umol/cm. Nitrate-nitrogen was extremely low, phosphorus low to moderate, and potassium was high to very high for all experiments and reference plots. Calcium, magnesium, and sulfur were high at all experiments and reference plots, while sodium was low.

Table 4-6. Data from the soil chemical properties were analyzed for simple descriptive statistics at Andrews, Baylor, and Kleberg Counties on sandy and clay soils during 2007.

Soil Analyses

Andrews		**Exp. 1**[3]	**Exp. 2**[3]	**Exp. 3**[3]	**Exp. 4**[3]	**RP**[3]
Sandy				Mean ± SE		
	pH	7.8 ± 0.08	7.6 ± 0.05	7.8 ± 0.06	-	7.8 ± 0.03
	Conductivity[1]	168.3 ± 12.7	169 ± 8.1	157 ± 8.2	-	225 ± 45.7
	N[2]	4.3 ± 0.85	5.3 ± 0.63	2.3 ± 0.48	-	3.3 ± 2.3
	P[2]	22 ± 1.1	17.5 ± 1.8	10.3 ± 1.1	-	20.5 ± 4.4
	K[2]	446.8 ± 19.4	424.5 ± 28.3	398.3 ± 5.7	-	374.5 ± 21.3
	Ca[2]	7365 ± 1062.6	5042.5 ± 144.6	4247 ± 246.8	-	6337 ± 1107.9
	Mg[2]	263.8 ± 22.5	197.3 ± 12.1	181 ± 4.8	-	308 ± 60.3
	S[2]	19 ± 3.5	13.5 ± 1.3	17.3 ± 3.0	-	24 ± 1.1
	Na[2]	192.3 ± 30.5	140.3 ± 7.7	198.5 ± 30.8	-	265.3 ± 10.4
Baylor						
Sandy						
	pH	7.3 ± 0.05	7.4 ± 0.05	7.2 ± 0.04	-	7.2 ± 0.40
	Conductivity	198.3 ± 14.3	139.5 ± 9.3	139.8 ± 12.5	-	141 ± 15.0
	N	7.3 ± 0.75	6 ± 0.71	6.0 ± 0.71	-	5.0 ± 0.0
	P	42.5 ± 9.3	23.3 ± 1.9	24 ± 1.4	-	51.5 ± 11.5
	K	472 ± 39.9	336.3 ± 20.8	303.3 ± 18.7	-	258 ± 38.0
	Ca	2371.5 ± 234.8	1674.5 ± 88.2	1655.3 ± 170.8	-	2040 ± 443.0
	Mg	341 ± 28.8	240.3 ± 18.1	182.5 ± 8.1	-	181 ± 49.0
	S	19 ± 1.3	15 ± 0.41	14.8 ± 0.48	-	17.5 ± 2.5
	Na	196.5 ± 4.0	189.5 ± 6.54	197.5 ± 7.2	-	189 ± 18.0
Clay						
	pH	7.6 ± 0.03	7.5 ± 0.04	7.4 ± 0.03	-	7.7 ± 0.05
	Conductivity	338.3 ± 10.3	273.5 ± 55.3	324 ± 24.3	-	325.5 ± 11.5
	N	2.8 ± 0.25	2.3 ± 0.23	3.3 ± 0.48	-	2.0 ± 1.0
	P	8.8 ± 0.25	6.8 ± 0.75	7.3 ± 0.48	-	8.0 ± 0.0
	K	476.3 ± 12.7	544 ± 20.1	510.5 ± 6.7	-	478 ± 21.0

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	Ca	8105.3 ± 293.6	7023.5 ± 160.1	6172.5 ± 226.2	-	8091 ± 274.0
	Mg	502.5 ± 22.8	510.3 ± 26.6	549.5± 32.4	-	498.5 ± 63.5
	S	22.3 ± 0.75	22.3 ± 1.5	14.3 ± 0.63	-	25.5 ± 2.5
	Na	223.8 ± 2.7	219.3 ± 11.0	202.5 ± 19.8	-	275 ± 43.0
Kleberg						
Sandy						
	pH	7.6 ± 0.07	7.5 ± 0.0	7.5 ± 0.0	7.6 ± 0.07	7.7 ± 0.03
	Conductivity	340 ± 8.8	296 ± 6.1	296 ±6.1	332 ± 4.3	343.8 ± 9.5
	N	4.3 ± 0.63	4.3 ± 0.48	4.3 ± 0.48	4.5 ± 1.2	3.5 ± 0.96
	P	10.5 ± 0.29	10.5 ± 0.29	10.5 ± 0.29	19 ± 1.8	14.5 ± 1.2
	K	568 ± 36.3	437 ± 11.7	437 ± 11.7	602.8 ± 18.0	601.3 ± 38.2
	Ca	23031 ± 3141	16115 ± 702.7	16115 ± 702.7	14695 ± 2537	19022 ± 3157
	Mg	563.5 ± 29.8	504 ± 11.4	504 ± 11.4	381.5 ± 36.1	512 ± 56.2
	S	35.8 ± 2.1	31.3 ± 0.25	31.3 ± 0.25	30.3 ± 1.7	32.8 ± 2.3
	Na	237.5 ± 6.5	238.5 ± 5.6	238.5 ± 5.6	216 ± 10.5	232.3 ± 5.6
Clay						
	pH	7.4 ± 0.3	7.5 ± 0.07	7.4 ± 0.03	7.4 ± 0.09	7.6 ± 0.03
	Conductivity	309.3 ± 19.4	341.5 ± 5.3	303.5 ± 1.4	325.5 ± 3.3	343 ± 7.0
	N	4.3 ± 0.48	4 ± 0.91	8.3 ± 0.63	4 ± 0.0	3.8 ± 1.7
	P	29.3 ± 1.9	18.3 ± 2.3	24.5 ± 2.5	22 ± 0.71	21.8 ± 1.1
	K	629 ± 27.8	458 ± 47.8	543.3 ± 18.5	456.5 ± 29.9	550.5 ± 28.8
	Ca	8112 ± 108.3	8588.8 ± 91.3	8475 ± 816.3	8767 ± 304.0	9919.3 ± 532.6
	Mg	424.8 ± 66.8	497.3 ± 37.4	305 ± 10.1	429 ± 10.9	402.5 ± 25.9
	S	21.3 ± 1.5	32.8 ± 0.75	20.5 ± 0.29	21.5 ± 1.8	27.5 ± 0.29
	Na	185 ± 12.4	218 ± 20.2	148.3 ± 9.2	169.5 ± 10.1	215 ± 1.8

[1]Measured in umol/cm

[2]Measured in ppm; N indicates nitrate-nitrogen; P indicates phosphorus; K indicates potassium; Ca indicates calcium; Mg indicates magnesium; S indicates sulfur; Na indicates sodium.

[3]Exp. 1 indicates samples from Revegetating Right of Ways with Native Seed Mixtures experiment; Exp. 2 indicates samples from Establishing Roadside Vegetation with Soil Retention Blankets experiment; Exp. 3 indicates samples from Replacing Bermudagrass with Native Windmillgrasses experiment; Exp. 4 indicates samples from Assessment of Two Commonly Used Seeding Techniques experiment; RP indicates samples from reference plots.

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5. MANAGEMENT IMPLICATIONS

5.1 Seeding Mixtures

The research results presented in this paper suggest planting a standard, native, or combination seed mixture will achieve the required vegetative cover at different locations and soil textures throughout Texas under similar precipitation patterns experienced during this study. However, based on the majority of species observed in both reference and treatment plots, it appears that the seed bank contributed considerably more to the canopy cover than the actual seed mixes planted. Under the conditions of this study, planting may not be necessary providing the soil contains an existing seed bank sufficient to stabilize disturbed areas by obtaining 70% vegetative cover, as compared to vegetation growing on adjacent property as quickly as possible. This suggests engineers need to consider the existing seed banks along roadsides prior to revegetating future projects. Additional seed bed preparation might also be necessary before revegetating if obtaining the species in the planted seed mixtures is the goal.

Although the canopy cover produced solely by native WMGs did not substantially add to the absolute percent canopy cover achieved, the lack of significant differences among treatments demonstrates the ability of these native grasses to establish and survive throughout Texas. Additional research on native grasses, specifically plant traits and characteristics, is essential in the successful restoration of our roadsides by providing a native alternative to introduced species that have been typically used. Evidence has proven that native plant species help blend roadsides back into the adjacent plant community (McFalls et al. 2007), reemphasizing the importance of using native plant species over introduced species.

5.2 Windmillgrass Accessions

Including a mixture of hooded and shortspike windmillgrass accessions in native seeding mixes may increase the range of adaptation of the seeding mix. This is because certain accessions may grow better than others depending on geographic location and soil texture. All treatments planted during 2007 produce sufficient absolute canopy cover to meet EPA standards and 2003 Texas Pollution Discharge Elimination System guidelines within 90 days of planting regardless of geographic location or soil texture when compared to adjacent reference plots.

5.3 Mowing

Native windmillgrasses survived standard mowing regimes with no negative effects to their growth. Their growth form and stoloniferous growth habit indicate they have the ability for long-term survival under mowing.

5.4 Soil Retention Blankets

According to the results from this study, application of soil retention blankets appeared to be unnecessary to produce sufficient absolute canopy cover to meet EPA standards and 2003 Texas Pollution Discharge Elimination System guidelines within 90 days of planting regardless of geographic location or soil texture. Soil retention blankets, however, may promote development of greater absolute canopy cover on sandy soils in the Rolling Plains and High Plains regions.

5.5 Seeding Techniques

Broadcast seeding can be used to achieve establishment of 70% absolute canopy cover (relative to reference plots), regardless of soil texture. Drilling, however, may result in greater canopy cover than broadcast seeding on clay soils. On sandy soils, broadcast seeding is better for establishing bermudagrass.

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7. APPENDICES

Table A-1. Native and introduced species used during study with number of seeds/kg, recommended seeding rates, and approximate cost/kg.

Species	number of seeds/kg	seeding rates[1]	cost[2]
hooded windmillgrass	1,154,090	0.56-0.90	$11.25
shortspike windmillgrass	1,478,315	0.90-1.12	$11.25
plains bristlegrass	13,185	3.36	$4.95
Lehmann lovegrass	2,940,750	1.12	$4.95
"Nezpar" Indian ricegrass	6,345	8.96-11.20	$5.40
Illinois bundleflower	28,800	14.56	$5.40
green sprangletop	242,100	1.90-2.24	$3.60
"Hachita" blue grama	319,950	1.68	$5.40
sand lovegrass	585,000	1.68	$3.60
sideoats grama	64,350	5.04	$4.50
"Ermello" weeping lovegrass	675,000	1.68	$3.15
"Cuerro" purple prairieclover	130,500	8.96-11.20	$7.20
bermudagrass	906,750	3.36-5.60	$1.80
buffelgrass	10,125	3.36-5.60	$4.50
sand dropseed	2,384,100	1.12	$3.15
"Woodward" sand bluestem	56,250	6.72	$5.40
Kleberg bluestem	384,300	2.24	$8.33
“Texoka" buffalograss	18,900	8.96	$3.60
western wheatgrass	54,000	10.08	$6.75

[1]kg/ha
[2]cost/kg

Table A-2. Texas Department of Transportation's Permanent Rural Seed Mixtures for Roadsides.

Texas Department of Transportation's Permanent Rural Seed Mixtures for Roadsides
Odessa District/Andrews County
Sandy:
green sprangletop (*Leptochloa dubia* (Kunth) Nees)
"Hachita" blue grama (*Bouteloua gracilis* (Willd. ex Kunth) Lag. ex Griffiths)
"Ermelo" weeping lovegrass (*Eragrostis curvula* (Schrad.) Nees)
sand dropseed (*Sporobolus cryptandrus* (Torr.) A. Gray)
purple prairieclover *(Dalea purpurea* Vent.)
Indian ricegrass (*Achnatherum hymenoides* (Roem. & Schult.) Barkworth)
Wichita Falls District/Baylor County
Sandy:
green sprangletop
bermudagrass (*Cynodon dactylon* (L.) Pers.)
sand bluestem (*Andropogon hallii* Hack.)
sand dropseed
sand lovegrass (*Eragrostis trichodes* (Nutt.) Alph. Wood)
"Ermelo" weeping lovegrass
purple prairieclover
Clay:
green sprangletop
bermudagrass
"El Reno" sideoats grama (*Bouteloua curtipendula* (Michx.) Torr.)
"Texoka" buffalograss (*Bouteloua dactyloides* (Nutt.) J.T. Columbus)
western wheatgrass (*Pascopyrum smithii* (Rydb.) A. Löve)
blue grama
Illinois bundleflower (*Desmanthus illinoensis* (Michx.) MacMill. ex B.L. Rob. & Fernald)
Corpus Christi District/Kleberg County
Sandy:
green sprangletop
bermudagrass
buffelgrass (*Pennisetum ciliare* (L.) Link)
sand lovegrass
Lehmann lovegrass (*Eragrostis lehmanniana* Nees)
purple prairieclover
Clay:
green sprangletop
bermudagrass
"Haskell" sideoats grama
"Texoka" buffalograss
plains bristlegrass (*Setaria vulpiseta* (Lam.) Roem. & Schult.)
Illinois bundleflower

Table A-3. Germination Rates.

Species	2006 % Germination	2007 % Germination
hooded windmillgrass (301)	60.25	73.25
hooded windmillgrass (313)	92.25	60.75
shortspike windmillgrass (260)	53.00	20.25
shortspike windmillgrass (283)	49.00	17.75
plains bristlegrass	29.25	52.75
Lehmann lovegrass	2.25	1.50
[1]"Nezpar" Indian ricegrass	7.75	2.50
Illinois bundleflower	68.75	75.50
green sprangletop	64.25	66.75
"Hachita" blue grama	73.50	77.75
"Woodward" sand bluestem	28.00	18.00
"Haskell" sideoats grama	47.75	5.00
"El Reno" sideoats grama	59.50	59.50
[2]Kleberg bluestem	13.50	17.25
Bermudagrass	69.00	84.25
Buffelgrass	11.00	46.50
"Ermello" weeping lovegrass	81.25	88.75
“Texoka" buffalograss	23.75	13.50
sand dropseed	16.50	2.50
[1]western wheatgrass	19.75	26.50
sand lovegrass	29.25	1.00
"Cuerro" purple prairieclover	20.75	42.75

Germination chamber 12 hrs. dark 20º C / 12 hrs. light 30º C; 28 day PLS estimates.
[1]Germination chamber 12 hrs. dark 15º C / 12 hrs. light 30º C; 14 day PLS estimates.
[2]Kleberg bluestem is no longer a part of TxDOT’s standard seeding mixture, but was used during this study.

Table A-4. 2006-2007 Pure Live Seed Calculations and Seeding Rates.

Seeding rates (g·m²) used during 2006 for Andrews County on sandy soils for the 3 treatments: TxDOT's standard permanent rural seed mixture, native seed mixture, and a combination of the standard and native seed mixes.

Treatment	Species	TxDOT's recommended seeding rates (g·m²)	Seeding rates used (g·m²) 2006
TxDOT	green sprangletop	0.61	0.97
	blue grama	1.62	19.87
	sand dropseed	0.81	14.75
	"Ermelo" weeping lovegrass	1.22	1.53
	Indian ricegrass	6.06	78.90
	purple prairieclover	1.02	5.78
Native	green sprangletop	0.61	0.97
	blue grama	1.62	19.87
	sand dropseed	0.81	14.75
	Indian ricegrass	6.06	78.90
	purple prairieclover	1.02	5.78
	[1]hooded windmillgrass (313)	1.02	1.14
	[1]shortspike windmillgrass (260)	1.02	1.98
Combination	green sprangletop	0.61	0.97
	blue grama	1.62	19.87
	sand dropseed	0.81	14.75
	"Ermelo" weeping lovegrass	1.22	1.53
	Indian ricegrass	6.06	78.90
	purple prairieclover	1.02	5.78
	[1]hooded windmillgrass (313)	1.02	1.14
	[1]shortspike windmillgrass (260)	1.02	1.98

[1]Hooded and shortspike windmillgrasses currently are not listed as part of TxDOT's standard permanent rural seed mixture. Suggested planting dates: 1 February to 15 May.

Table A-4. Seeding rates (g·m²) used during 2006-2007 for Baylor County on sandy soils for the 3 treatments: TxDOT's standard permanent rural seed mixture, native seed mixture, and a combination of the standard and native seed mixes (Continued).

2006-2007 Pure Live Seed Calculations and Seeding Rates				
			Seeding rates used (g·m²)	
Treatment	Species	TxDOT's recommended seeding rates (g·m²)	2006	2007
TxDOT	green sprangletop	0.61	0.97	0.96
	bermudagrass	2.42	3.51	2.93
	sand dropseed	0.81	14.75	32.53
	sand bluestem	4.85	248.71	43.81
	sand lovegrass	0.61	18.94	61.61
	"Ermelo" weeping lovegrass	1.21	1.52	1.39
	purple prairieclover	1.02	5.78	2.80
Native	green sprangletop	0.61	0.97	0.96
	sand dropseed	0.81	14.75	32.53
	sand bluestem	4.85	248.71	43.81
	sand lovegrass	.61	18.94	61.61
	purple prairieclover	1.02	5.78	2.80
	[1]hooded windmillgrass (313)	1.02	1.14	1.77
	[1]shortspike windmillgrass (260)	1.02	1.98	5.30
Combination	green sprangletop	0.61	0.97	0.96
	bermudagrass	2.42	3.51	2.93
	sand dropseed	0.81	14.75	32.53
	sand bluestem	4.85	248.71	43.81
	sand lovegrass	.61	18.94	61.61
	"Ermelo" weeping lovegrass	1.21	1.52	1.39
	purple prairieclover	1.02	5.78	2.80
	[1]hooded windmillgrass (313)	1.02	1.14	1.77
	[1]shortspike windmillgrass (260)	1.02	1.98	5.30

[1]Hooded and shortspike windmillgrasses currently are not listed as part of TxDOT's standard permanent rural seed mixture. Suggested planting dates: 1 February to 15 May.

Table A-4. Seeding rates (g·m²) used during 2006-2007 for Baylor County on clay soils for the 3 treatments: TxDOT's standard permanent rural seed mixture, native seed mixture, and a combination of the standard and native seed mixes (Continued).

2006-2007 Pure Live Seed Calculations and Seeding Rates				
			Seeding rates used (g·m²)	
Treatment	Species	TxDOT's recommended seeding rates (g·m²)	2006	2007
TxDOT	green sprangletop	0.61	0.97	0.96
	"El Reno" sideoats grama	5.46	9.94	9.64
	bermudagrass	1.82	2.64	2.20
	"Texoka" buffalograss	3.23	14.54	25.43
	western wheatgrass	4.24	27.25	19.48
	"Hachita" blue grama	1.21	14.85	52.60
	Illinois bundleflower	2.03	2.96	2.69
Native	green sprangletop	0.61	0.97	0.96
	"El Reno" sideoats grama	5.46	9.94	9.64
	"Texoka" buffalograss	3.23	14.54	25.43
	western wheatgrass	4.24	27.25	19.48
	"Hachita" blue grama	1.21	14.85	52.60
	Illinois bundleflower	2.03	2.96	2.69
	[1]hooded windmillgrass (313)	1.02	1.14	1.77
	[1]shortspike windmillgrass (260)	1.02	1.98	5.30
Combination	green sprangletop	0.61	0.97	0.96
	"El Reno" sideoats grama	5.46	9.94	9.64
	bermudagrass	1.82	2.64	2.20
	"Texoka" buffalograss	3.23	14.54	25.43
	western wheatgrass	4.24	27.25	19.48
	"Hachita" blue grama	1.21	14.85	52.60
	Illinois bundleflower	2.03	2.96	2.69
	[1]hooded windmillgrass (313)	1.02	1.14	1.77
	[1]shortspike windmillgrass (260)	1.02	1.98	5.30

[1]Hooded and shortspike windmillgrasses currently are not listed as part of TxDOT's standard permanent rural seed mixture. Suggested planting dates: 1 February to 15 May.

Table A-4. Seeding rates (g·m²) used during 2006-2007 for Kleberg County on sandy soils for the 3 treatments: TxDOT's standard permanent rural seed mixture, native seed mixture, and a combination of the standard and native seed mixes (Continued).

2006-2007 Pure Live Seed Calculations and Seeding Rates				
			Seeding rates used (g·m²)	
Treatment	Species	TxDOT's recommended seeding rates (g·m²)	2006	2007
TxDOT	green sprangletop	0.61	0.97	0.96
	bermudagrass	3.65	5.30	4.42
	"Common" buffelgrass	0.81	7.75	1.83
	sand lovegrass	1.22	37.88	123.23
	Lehmann lovegrass	1.21	55.76	122.35
	[2]Kleberg bluestem	1.62	20.48	16.02
	purple prairieclover	1.02	5.78	2.80
Native	green sprangletop	0.61	0.97	0.96
	sand lovegrass	1.22	37.88	123.23
	purple prairieclover	1.02	5.78	2.80
	[1]hooded windmillgrass (313)	1.02	1.14	1.77
	[1]shortspike windmillgrass (260)	1.02	1.98	5.30
Combination	green sprangletop	0.61	0.97	0.96
	bermudagrass	3.65	5.30	4.42
	"Common" buffelgrass	0.81	7.75	1.83
	sand lovegrass	1.22	37.88	123.23
	Lehmann lovegrass	1.21	55.76	122.35
	[2]Kleberg bluestem	1.62	20.48	16.02
	purple prairieclover	1.02	5.78	2.80
	[1]hooded windmillgrass (313)	1.02	1.14	1.77
	[1]shortspike windmillgrass (260)	1.02	1.98	5.30

[1]Hooded and shortspike windmillgrasses currently are not listed as part of TxDOT's standard permanent rural seed mixture. Suggested planting dates: 1 January to 1 May.
[2]Kleberg bluestem is no longer listed as a species in TxDOT's standard permanent rural seed mixture but was included in this study.

Table A-4. Seeding rates (g·m²) used during 2006-2007 for Kleberg County on clay soils for the 3 treatments: TxDOT's standard permanent rural seed mixture, native seed mixture, and a combination of the standard and native seed mixes (Continued).

2006-2007 Pure Live Seed Calculations and Seeding Rates				
			Seeding rates used (g·m²)	
Treatment	Species	TxDOT's recommended seeding rates (g·m²)	2006	2007
TxDOT	green sprangletop	0.61	0.97	0.96
	"Haskell" sideoats grama	5.46	85.58	82.85
	bermudagrass	3.65	5.30	4.42
	"Texoka" buffalograss	3.65	16.43	28.76
	Plains bristlegrass	2.43	8.32	4.84
	Illinois bundleflower	2.03	2.96	2.69
	[2]Kleberg bluestem	1.62	20.48	16.02
Native	green sprangletop	0.61	0.97	0.96
	"Haskell" sideoats grama	5.46	85.58	82.85
	"Texoka" buffalograss	3.65	16.43	28.76
	Plains bristlegrass	2.43	8.32	4.84
	Illinois bundleflower	2.03	2.96	2.69
	[1]hooded windmillgrass (313)	1.02	1.14	1.77
	[1]shortspike windmillgrass (260)	1.02	1.98	5.30
Combination	green sprangletop	0.61	0.97	0.96
	"Haskell" sideoats grama	5.46	85.58	82.85
	bermudagrass	3.65	5.30	4.42
	"Texoka" buffalograss	3.65	16.43	28.76
	Plains bristlegrass	2.43	8.32	4.84
	Illinois bundleflower	2.03	2.96	2.69
	[2]Kleberg bluestem	1.62	20.48	16.02
	[1]hooded windmillgrass (313)	1.02	1.14	1.77
	[1]shortspike windmillgrass (260)	1.02	1.98	5.30

[1]Hooded and shortspike windmillgrasses currently are not listed as part of TxDOT's standard permanent rural seed mixture. Suggested planting dates: 1 January to 1 May.
[2]Kleberg bluestem is no longer listed as a species in TxDOT's standard permanent rural seed mixture but was included in this study.

Table A-4. Seeding rates (g·m²) used during 2006-2007 for Andrews, Baylor, and Kleberg Counties on sandy and clay soils for the soil retention blanket experiments and monoculture experimental plots 5 treatments (Continued).

2006-2007 Seeding Rates		
	Seeding rates used (g·m²)	
Treatment	**2006**	**2007**
260 SS[1]	2.18	11.12
283 SS[1]	2.18	12.69
301 H[1]	2.36	3.55
313 H[1]	1.54	4.28
BER[1]	2.54	4.24

[1]260 SS indicates shortspike WMG accession number 9085260; 283 SS indicates shortspike WMG accession number 9085283; 301 H indicates hooded WMG accession number 9085301; 313 H indicates hooded WMG accession number 9085313; BER indicates bermudagrass.

Table A-4. Seeding rates ($g{\cdot}m^2$) used during 2006 for Kleberg County on sandy and clay soils for the seeding techniques experiments (Continued).

Treatment	Species	Seeding rates used ($g{\cdot}m^2$)
Drill	green sprangletop	2.94
	260 SS[1]	1.98
	313 H[1]	1.14
	BER[1]	3.52
Broadcast	green sprangletop	2.94
	260 SS	1.98
	313 H	1.14
	BER	3.52

[1]260 SS indicates shortspike WMG accession number 9085260; 313 H indicates hooded WMG accession number 9085313; BER indicates bermudagrass.