SOD-SEEDING LOW MAINTENANCE PLANT SPECIES INTO COASTAL BERMUDAGRASS SOD ON LIGNITE OVERBURDEN IN TEXAS[1]

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Abstract.--Introducing plant species into grass pastures by sod-seeding and interseeding has long been recognized as a method for improving forage quantity and quality without increasing cultural inputs. This study was conducted to test the ability of low-maintenance plant species to establish and coexist with Coastal bermudagrass established on reclaimed lignite overburden in Texas. Three grasses (Indiangrass (Sorghastrum nutans), sideoats grama (Bouteloua curtipendula), and switchgrass (Panicum virgatum)), two legumes (Illinois bundleflower (Desmanthus illinoensis) and sericea lespedeza (Lespedeza cuneata)), and one forb (Maximilian sunflower (Helianthus maximiliani)) were sod-seeded singly into herbicide-treated and untreated, 2- and 8-year-old Coastal bermudagrass swards. These species were also seeded into overburden with no vegetative cover. Sod-seeded, warm-season grasses did not establish in either aged sward during the first 2 growing seasons despite sod suppression with glyphosate herbicide in 25 cm bands. However, the grass species were finally observed the 3rd growing season in the 8-year-old sod where herbicide had been applied. These same grasses established and persisted on overburden which had not been previously revegetated. Illinois bundleflower, sericea lespedeza, and Maximilian sunflower were observed the first growing season in both swards of Coastal bermudagrass where herbicide had been applied and during the 2nd year in non-herbicide bermudagrass plots. Their persistance during subsequent years was attributed to regenerative strategies and growth habits that reduced competitive interactions with Coastal bermudagrass sod. Sod-seeding low-maintenance species into Coastal bermudagrass sod shows promise for enhancing diversity and increasing productivity on surface-mined areas in Texas.

INTRODUCTION

Approximately 1.1 million hectares of land have been leased for lignite mining in the Pineywoods, Post Oak Savannah, and South Texas Plains vegetation regions of east and south-central Texas (Dickson and Vance 1981, Railroad Commission of Texas 1982). Near-surface, strippable lignite reserves found at depths between 6.1 and 61 m are estimated to be 10,072 million metric tons, and deep-basin reserves at depths between 61 and 610 m amount to approximately 31,588 million metric tons (Railroad Commission of Texas 1982). Most surface mine operations removed all overburden materials above lignite seams without segregating topsoil. Following mining, mixed overburden was graded to approximate original contour and prepared for revegetation.

In Texas, several introduced perennial grasses, including various bermudagrass (Cynodon dactylon) varieties (Coastal, common, Midland, NK-37), Kleingrass (Panicum coloratum), bahiagrass (Paspalum notatum), and buffelgrass (Cenchrus ciliaris) have been used in mine-land revegetation programs (Hons et al. 1980, White 1975). Of these grasses Coastal bermudagrass is the most widely used plant species for revegetation because it is adapted to many environmental and soil conditions, it is drought and disease tolerant, and it achieves rapid surface coverage and a large root mass with high rates of nitrogen fertilizer (Burton and Hanna 1985, Hons et al. 1979). Under intensive management, Coastal bermudagrass stabilizes the overburden for erosion control, maintains high yields, and provides a solid base for livestock production (Hons et al. 1980). However, lower surface coverage, and forage yield and quality are obtained with lower fertilization rates and less intensive management (Fisher and Caldwell 1959, Heizer 1981). Intensive management is expensive and will increase as energy costs rise. Therefore, a major concern is the ability of Coastal bermudagrass to persist under suboptimal fertility levels and less intensive management schemes after the reclaimed land has been returned to the original land owners following bond release (Wells 1985).

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Sod-seeding and interseeding provide a means of introducing low-maintenance forage species into bermudagrass swards on surface-mined lands. Coastal bermudagrass would provide short-term site stabilization while sod-seeded, low-maintenance species would enhance the long-term development of more diverse, stable plant communities requiring fewer inputs, and support alternate land uses on reclaimed areas. Coastal bermudagrass swards could be modified and managed for general rangeland use, recreational use, and wildlife habitat, while other areas could remain as Coastal bermudagrass pastures for livestock and hay production. This approach could create a mosaic of vegetation types and promote multiple use of resources on large areas of reclaimed land (Smeins 1980).

Many low-maintenance plant species have potential for seeding on surface-mined lands in Texas (Ambrose et al. 1983, Dickson and Vance 1981, Thornburg 1982, Vogel 1981, and Wasser 1982) but little information is available concerning their ability to coexist with Coastal bermudagrass. The objective of this study was to evaluate the establishment and growth of six low-maintenance species sod-seeded into 2 different-aged Coastal bermudagrass swards on lignite overburden, and seeded into unreclaimed lignite overburden.

SITE DESCRIPTIONS

Three study sites were selected in 1982 near Fairfield, Texas (160 km southeast of Dallas) in the Post Oak Savannah vegetation region (Gould 1975). The average annual precipitation of the area is 97 cm, with May and September being the peak rainfall months. The mean minimum January temperature is 3°C while the mean maximum July temperature is 35°C (National Oceanic and Atmospheric Administration 1983). Prior to mining, soils were characterized by a thin, fine sandy loam topsoil overlying a thick, plastic, clayey subsoil, and were classified in the fine, montmorillonitic, thermic Udertic Paleustalfs (Hons et al. 1979).

The three study sites, located within 1.5 km of each other on the Texas Utilities Company's Big Brown Mine, represented an 8-year-old reclaimed area (mined in 1975), a 2-year-old reclaimed area (mined in 1981), and an untreated area of recently leveled overburden (mined in 1981). During the mining process, all overburden materials (ranging in depth from 20 to 30 m) above the lignite seams were removed without segregating the topsoil (White 1975). Following mining, mixed overburden was graded to approximate original contour at all three sites, and the 2- and 8-year-old sites were sprigged with Coastal bermudagrass at a rate of 21 $hl \cdot ha^{-1}$. A total of 201-48-94 kg $N\text{-}P\text{-}K \cdot ha^{-1}$ of fertilizer was applied in three split applications (78-28-54 kg $N\text{-}P\text{-}K \cdot ha^{-1}$ at sprigging in early spring, 75 kg $N \cdot ha^{-1}$ in early summer and 54-20-40 kg N-P-K in fall) during the first year of Coastal bermudagrass establishment on the 2- and 8-year-old sites. During subsequent years fertilizer rates were reduced to 54-20-40 kg $N\text{-}P\text{-}K \cdot ha^{-1}$ in the spring, 75 kg $N \cdot ha^{-1}$ in early summer, and 36-14-28 kg $N\text{-}P\text{-}K \cdot ha^{-1}$ in the fall, for an annual total of 165-34-68 kg $N\text{-}P\text{-}K \cdot ha^{-1}$. The 8-year-old site was returned to a local rancher in 1981. In 1981 the site was fertilized with 54-20-40 kg $N\text{-}P\text{-}K \cdot ha^{-1}$ in the spring and cut for hay in June and August. The site was then grazed by cattle (1.5 $ha \cdot AU^{-1}$) for 20 months without further fertilization prior to the initiation of the study in March 1983. The untreated site was not artificially revegetated or fertilized prior to the initiation of the study. The three sites, approximately 1 ha each in size, were fenced to prevent grazing by livestock during the study period.

MATERIALS AND METHODS

Sod suppression by herbicide was deemed necessary in order to establish plant species in Coastal bermudagrass (Kalmbacher et al. 1980, Samson and Moser 1982). One week prior to sod-seeding in March 1983, glyphosate herbicide (N-(phosphonomethyl) glycine) was sprayed on one-half of the 2- and 8-year-old Coastal bermudagrass sites at a rate of 5.6 liters $a.i. \cdot ha^{-1}$ in 25-cm wide bands (separated by 25-cm wide unsprayed bands). Six low-maintenance, warm-season, perennial plant species (Table 1) were seeded into herbicide-treated and untreated Coastal bermudagrass sod and into nonvegetated overburden at a depth of 2 cm on 50-cm wide row spacings using a Tye Pasture Pleaser. Seeding rates were based on recommendations for 50-cm wide row spacings on prepared seedbeds (Table 1) (Welch and Haferkamp 1980). Seed rows were located in the middle of the 25-cm wide bands on the herbicide-treated sod. The three sites received no fertilizer during the study period. Plots were 20 m long by 2 m wide, with three replications per treatment. Densities of seeded species were measured in five randomly located 1-m long row sections in each plot during the 1983 and 1984 growing seasons. In September of each growing season, aboveground biomass of seeded species and Coastal bermudagrass (2- and 8-year-old sites) was clipped at ground level in five randomly located 1-m long by 0.25-m wide quadrats in each plot, dried at 65°C for 48 hours, and weighed. Analysis of variance and Duncan's new multiple range test ($p < 0.05$) were used to interpret density and aboveground biomass data (Steel and Torrie 1980). In September 1984, 1.5-m deep pits were excavated in several plots to observe root characteristics (tap vs. fibrous rooting habit, distribution and depth of rooting) of seeded species which had established in Coastal bermudagrass and in nonvegetated overburden.

Soil samples were taken to a depth of 25 cm at 5 randomly located points at each site in March 1983. Soils were analyzed for texture, pH, and several nutrient elements by the Soil Testing Laboratory at Texas A&M University (Table 2). Precipitation data was also collected and measured by a standard rain gauge on the Big

Table 1. Plant species and pure live seed (PLS) rates used in sod-seeding of 2- and 8-year-old Coastal bermudagrass sites and seeding of nonvegetated overburden site.

Species			PLS Rate ($kg \cdot ha^{-1}$)
Grasses			
'Lometa'	Indiangrass	(Sorghastrum nutans)	5.6
'Haskell'	Sideoats grama	(Bouteloua curtipendula)	5.6
'Alamo'	Switchgrass	(Panicum virgatum)	2.2
Legumes			
'Sabine'	Illinois bundleflower	(Desmanthus illinoensis)	1.7
'Okinawa'	Sericea lespedeza	(Lespedeza cuneata)	5.6
Forbs			
'Aztec'	Maximilian sunflower	(Helianthus maximiliani)	1.1

Brown Mine during the study period (Table 3). Monthly precipitation values were compared to normal monthly precipitation values for a 30-year time period (National Oceanic and Atmospheric Administration 1983).

RESULTS AND DISCUSSION

Precipitation received during 1983 and 1984 was slightly lower than the long-term average annual precipitation for the area (Table 3). Precipitation received during April 1983 was very low relative to the long-term average rainfall for April. During 1984, a summer-long drought occurred from April through September. Only 25 cm of precipitation fell during these 6 months when 51 cm of rain are normally received. These dry periods had differing effects on seeded species germination, establishment, and persistence at the three sites.

Indiangrass, switchgrass, and sideoats grama plants were not observed in herbicide-treated or untreated, 2- or 8-year-old bermudagrass sods during 1983 and 1984. Inadequate rainfall during the normally optimum period for warm season grass establishment (Welch and Haferkamp 1980), coupled with competition for limited soil moisture with established Coastal bermudagrass, may have severely limited germination and seedling growth of these seeded grasses (Vassey et al. 1985). When seeded into nonvegetated overburden, these grasses established and persisted (Table 4) despite the low rainfall during April 1983 and the summer drought of 1984. The droughty conditions during 1984 reduced Indiangrass and switchgrass densities and aboveground biomass. However, sideoats grama, a more drought-resistant species, increased in density and aboveground biomass production during the 1984 growing season. Indiangrass and switchgrass densities of 1.0 and .5 plants per meter of row length, respectively, were observed on the 8-year-old Coastal bermudagrass site in June 1985 (the third year after sod-seeding). Evidently, as time passed and cultural inputs were reduced, these two seeded grass species were eventually capable of establishing in the older, less-competitive sod. Several researchers (Bryan et al. 1984, Samson and Moser 1982) found it necessary to completely suppress the grass sod for first year establishment of sod-seeded, warm-season grasses. Sod-seeding switchgrass in Nebraska (Samson and Moser 1982) required greater than 85% grass suppression compared to 50% suppression applied in this study.

Illinios bundleflower did not establish on the 2-year-old site during the first year, but seedlings did establish from hard seed on the herbicide-treated area on this site during the second growing season (Table 5). Bundleflower establishment in herbicide-treated, 8-year-old Coastal bermudagrass was similar to its establishment in nonvegetated overburden, and droughty conditions during 1984 reduced its density on both sites. Sericea lespedeza density

Table 2. Physical and chemical characteristics of overburden on the 2- and 8-year-old Coastal bermudagrass sites and the nonvegetated site.

Site	Texture	pH	PPM					
			N	P	K	Ca	Mg	Na
2-year-old bermudagrass	Silty clay loam	7.3	6	50	331	2090	>500	100
8-year-old bermudagrass	Silty clay loam	6.5	7	43	318	2670	>500	105
Nonvegetated overburden	Silty clay loam	7.6	<1	3	160	1800	415	150

Table 3. Precipitation (cm) received during 1983 and 1984 and the long-term (30-year) average at Fairfield, Texas.

Month	1983	1984	Average
Jan	2.51	3.66	6.50
Feb	13.79	8.33	6.73
Mar	10.08	9.60	7.44
Apr	.51	3.58	11.53
May	20.24	3.30	11.61
Jun	10.59	10.51	7.44
Jul	8.03	2.06	4.14
Aug	7.42	1.60	6.78
Sep	4.50	3.96	9.96
Oct	1.88	23.50	9.04
Nov	6.12	7.87	8.03
Dec	5.38	10.77	7.85
Total	91.06	88.75	97.05

was also low in herbicide-treated, 2-year-old Coastal bermudagrass relative to the other sites. However, unlike Illinois bundleflower, sericea lespedeza showed a trend of increasing density from 1983 to 1984 in spite of the summer drought during 1984. Maximilian sunflower density was greater on the 8-year-old, herbicide-treated site than on the 2-year-old, herbicide-treated site. Due to insufficient seed, this species was not seeded into nonvegetated overburden, but results from other seeding trials in nonvegetated overburden (Robert Knight, unpublished data) indicate that Maximilian sunflower would have established very well on the nonvegetated site. Droughty conditions had little effect on Maximilian sunflower densities on the 2- and 8-year-old bermudagrass sites from 1983 to 1984. These three plants were not observed during 1983 in 2- or 8-year-old Coastal bermudagrass plots which had not been treated with herbicide. However, during 1984, densities of 1.2, 1.7, and 3.5 plants per meter of row length were measured for Illinois bundleflower, sericea lespedeza, and Maximilian sunflower, respectively, on the 8-year-old, non-herbicide bermudagrass plots. Only sericea lespedeza was found growing in untreated, 2-year-old Coastal bermudagrass, and its density was very low (0.5 plants per meter of row).

Aboveground biomass production of Illinois bundleflower, sericea lespedeza and Maximilian sunflower increased from 1983 to 1984 on herbicide-treated, 2-year-old and 8-year-old Coastal bermudagrass sites (Table 6). On nonvegetated spoil, both legumes showed decreases in aboveground biomass production. Soon after planting, this nonvegetated site experienced rill erosion due to the slow development and sparse ground cover of these seeded species. Gullies (10 to 20 cm deep) were created after the first year which indicated that much of the rainfall received on this area was running off and removing considerable amounts of overburden. On the other hand, the bermudagrass sites trapped and held more moisture so that erosion did not occur, thereby enhancing water infiltration into the vegetated overburden to a greater degree than the nonvegetated site. The moisture stored during cooler months was used by plants growing prior to the activation of the dormant bermudagrass. As a result less stress may have been placed on the seeded species, which allowed them to increase their productivity in Coastal bermudagrass. During 1983, the 8-year-old Coastal bermudagrass sod exhibited less vigor and productivity than the 2-year-old sward (4585 and 6795 $kg \cdot ha^{-1}$ of aboveground biomass, respectively), and may have been less competitive during the establishment period of the seeded species. This less productive sod may have permitted more light and water to be available to the seedlings for growth and establishment (Groya and Sheaffer 1981, Kalmbacher 1985, Wilkinson and Gross 1964). Productivity of both sods was very similar (5608 $kg \cdot ha^{-1}$ and 5780 $kg \cdot ha^{-1}$ on the 8- and 2-year-old sites, respectively) during the 1984 drought period.

In an effort to understand the reasons for Maximilian sunflower, Illinois bundleflower, and sericea lespedeza germination, establishment and persistence in the Coastal bermudagrass sods, several aspects of their establishment and regenerative strategies must be considered (Grime 1979). Maximilian sunflower is a warm-season, perennial forb which reproduces from seed and persistent rhizomes. Plants generally produce numerous, small, wind-dispersed seeds which germinate over a wide range of temperature and moisture regimes (Owens and Call 1985). After plants have established, they spread rapidly by

Table 4. Density (number of plants per m of row length) and aboveground biomass ($kg \cdot ha^{-1}$) of grass species seeded in overburden with no vegetation cover.

Species	1983		1984	
	Density	Aboveground biomass	Density	Aboveground biomass
Indiangrass	3.7[a*]	3689[a]	1.6[a]	2959[a]
Sideoats grama	1.2[a]	828[a]	2.4[a]	1988[b]
Switchgrass	6.3[a]	6067[a]	2.0[b]	2015[b]

*Means within species across years for density or aboveground biomass with the same letter are not significantly different at $p < .05$.

Table 5. Density (number of plants per m of row length) of legume and forb species seeded in 2- and 8-year-old Coastal bermudagrass swards and in overburden with no vegetation cover.

Species	1983			1984		
	2-year-old bermudagrass	8-year-old bermudagrass	Nonvegetated overburden	2-year-old bermudagrass	8-year-old bermudagrass	Nonvegetated overburden
Illinois bundleflower	0[b*]	4.7[a]	4.2[a]	.3[b]	2.3[b]	1.4[b]
Sericea lespedeza	.4[c]	4.9[b]	7.8[ab]	1.5[c]	6.6[ab]	9.2[a]
Maximilian sunflower	1.5[b]	7.9[a]	–	2.9[a]	8.9[a]	–

* Means within a species with the same letter are not significantly different at $p < .05$.

aggressive rhizomes and form dense colonies (Wasser 1982). The rhizomes and crown of this plant provide it with the ability to mobilize resources to enable it to compete with Coastal bermudagrass rhizomes. These two distinct regenerative strategies allow Maximilian sunflower to exploit vegetation gaps. This sunflower also initiates spring growth in mid February/early March which generally is 4 to 8 weeks prior to Coastal bermudagrass activity, and its tall growth form allows it to grow above the sod in order to receive light.

Illinois bundleflower is a herbaceous, perennial legume of wide distribution throughout the midwestern U.S. It produces seed during mid-summer and maintains itself during winter months by buds located below the soil surface (Latting 1961). The plant has a large, deep, woody taproot which can penetrate below the mass of Coastal bermudagrass roots enabling it to exploit resources from greater depths in the overburden profile. Due to its nitrogen-fixing capability, it is not dependent on soil nitrogen, as is Coastal bermudagrass. This bundleflower also initiates growth several weeks earlier in the spring before Coastal bermudagrass, and it rapidly grows over the sodgrass canopy.

Sericea lespedeza is grown widely in the southeastern U.S. for forage and seed production (Hoveland and Anthony 1974). During the first growing season this legume maintains an herbaceous growth habit, but without mowing or grazing it becomes an upright, bushy shrub. Sericea lespedeza has a taproot which penetrates deeply into the overburden and provides the plant with resources which the bermudagrass does not fully exploit. It initiates growth earlier in the spring than Coastal bermudagrass, fixes atmospheric nitrogen, and is sufficiently tall to grow over the sodgrass.

In summary, sod suppression with herbicide was necessary for first year establishment of sod-seeded species in 2- and 8-year-old Coastal bermudagrass swards. Densities and aboveground biomass production of the seeded species were greater on the older, less dense and less vigorous bermudagrass sod. These sod-seeded species exhibit strategies which enable them to persist in Coastal bermudagrass following initial establishment. Their persistance was related to their early spring growth which allowed growth above the sodgrass for light, and allowed utilization of stored winter moisture in the overburden beneath the dormant sodgrass. The deep, taproot systems of the legumes also provided the ability to explore deeper areas of the overburden where there was less competition for nutrients and water. As these plants persist in the sod, they enhance diversity and productivity on the site, and contribute to wildlife habitat and other post-mining land uses.

Table 6. Aboveground biomass production ($kg \cdot ha^{-1}$) of legume and forb species seeded in 2- and 8-year-old Coastal bermudagrass swards and in overburden with no vegetation cover.

Species	1983			1984		
	2-year-old bermudagrass	8-year-old bermudagrass	Nonvegetated overburden	2-year-old bermudagrass	8-year-old bermudagrass	Nonvegetated overburden
Illinois bundleflower	0[a*]	290[b]	761[a]	400[ab]	618[a]	176[b]
Sericea lespedeza	4[c]	388[c]	1100[b]	1581[b]	3480[a]	600[bc]
Maximilian sunflower	49[b]	325[b]	–	827[b]	2902[a]	–

* Means within a species with the same letter are not significantly different at $p < 0.05$.

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