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South Texas Native Plant Restoration Project
Final Report

Technical Report 0-4570-1

Cooperative Research Program

CAESAR KLEBERG WILDLIFE RESEARCH INSTITUTE
TEXAS A&M UNIVERSITY–KINGSVILLE
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The South Texas Native Plant Restoration Project was a resounding success in that the primary goal of developing commercial sources of native seed has been substantially met. By the conclusion of the project on August 31, 2011, 20 native seed sources had been developed or aided in being commercialized because of this project. Ecotypic native seeds are today commercially available for use by the Texas Department of Transportation, and the methods to plant, establish, and manage these native species along roads in Texas have been tested, reported on, and are available for vegetation managers reference and implementation. We graciously thank the Texas Department of Transportation and its Commissioners, employees, and contractors for their tremendous collaborative nature and unyielding support that made such successes possible.

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SOUTH TEXAS NATIVE PLANT RESTORATION PROJECT FINAL REPORT

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Texas AgriLife Research Station-Beeville and Uvalde
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Pogue Agri Partners
Turner Seed Company
Bamert Seed Company
and Private landowners of South Texas

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DISCLAIMER

The contents of this report reflect the views of the authors, who are responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official view or policies of the Federal Highway Administration (FHWA) or the Texas Department of Transportation (TxDOT). This report does not constitute a standard, specification, or regulation. Mention of trade names or commercial products does not constitute an endorsement or recommendation for use. The researcher in charge of the project from 2001–2008 was Paula D. Maywald, and from 2009–2011 was Forrest S. Smith.

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EXECUTIVE SUMMARY

The South Texas Native Plant Restoration Project was a resounding success in that the primary goal of developing commercial sources of native seed has been substantially met. By the conclusion of the project on August 31, 2011, 20 native seed sources had been developed or aided in being commercialized because of this project. Ecotypic native seeds are today commercially available for use by the Texas Department of Transportation, and the methods to plant, establish, and manage these native species along roads in Texas have been tested, reported on, and are available for vegetation managers reference and implementation. We graciously thank the Texas Department of Transportation and its Commissioners, employees, and contractors for their tremendous collaborative nature and unyielding support that made such successes possible.

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CHAPTER 1: INTRODUCTION

Figure 1.1. Seeding a Recently Completed Right of Way along US HWY 77 in South Texas.

Restoring vegetative cover on disturbed or engineered soils following roadway construction is a minor part of the overall workload of the Texas Department of Transportation (TxDOT). But the resultant plant communities that exist along Texas' 80,000 miles of roadways may well be the most visible and cared about portion of a roadway to many members of the public, natural resource managers, and especially adjacent landowners. Historic (TxDOT 1995) and recent (TxDOT 2004) use of exotic grasses for erosion control is a major complaint against the agency. While little empirical evidence has been gathered to support it, the near-consensus conclusion among the general public and natural resource managers is that TxDOT use of exotic grasses such King Ranch bluestem (*Bothriochloa ischaemum* L. Keng) and Bermudagrass (*Cynodon dactylon* (L.) Pers.) along roadways is the primary reason for their current prevalence in the state of Texas. Other common exotic grasses on Texas roadsides, such as Kleberg bluestem (*Dichanthium annulatum* (Forssk.) Stapf.), Johnsongrass (*Sorghum halepense* (L.) Pers.), Wilman lovegrass (*Eragrostis superba* Peyr.), and guineagrass (*Urochloa maxima* (Jacq.) R. Webster) have not been specified for use, or planted by the agency, yet do exist on and spread from TxDOT rights of way.

In south Texas (Laredo, San Antonio, Corpus Christi, and Pharr TxDOT Districts), TxDOT (2004) (Figure 1.1) seed mixture specifications include both native and exotic grass seed in order to establish permanent vegetation for erosion control on highway rights of way. Exotic species include Bermudagrass, buffelgrass (*Pennisetum ciliare* (L.) Link), and Lehmann lovegrass (*Eragrostis lehmanniana* Nees). Ecotypic seeds of native plant species specified for south Texas districts were not available commercially before this project. Substantial evidence suggests native seeds used for restoration and reclamation should originate from populations from the same ecosystem as the planting site in order for best performance (Johnson et al. 2010). TxDOT districts in south Texas fall primarily within the Gulf Prairies and Marshes and South Texas Plains ecoregions of Texas (Gould 1969) (Figure 1.2).

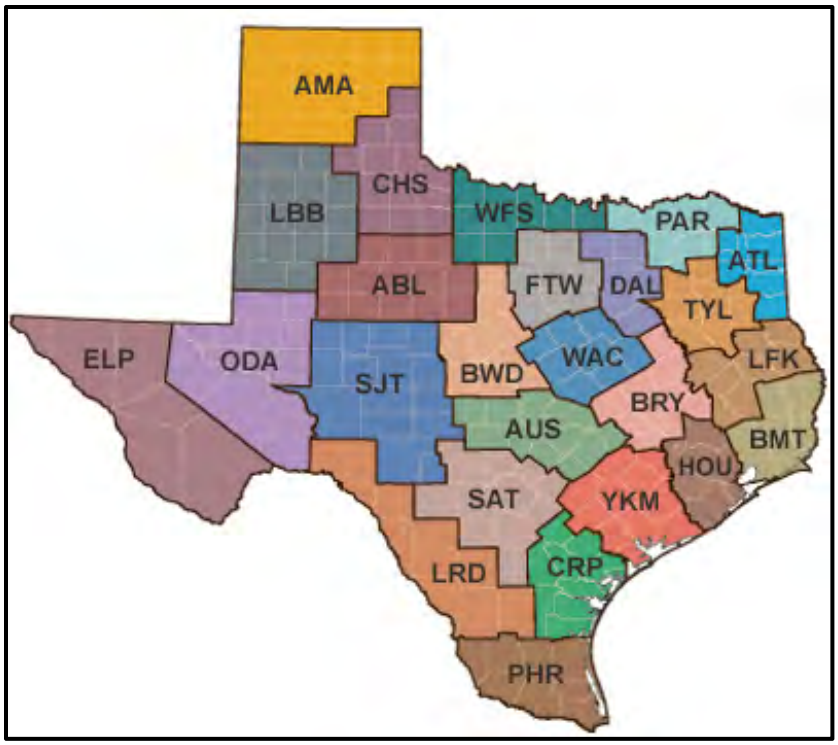

Figure 1.2. Map of Texas Department of Transportation Districts, Courtesy Texas Department of Transportation.

Native species included in current TxDOT specifications for south Texas include the grasses green sprangletop (*Leptochloa dubia* (Kunth) Nees), sideoats grama (*Bouteloua curtipendula* (Michx.) Torr.), plains bristlegrass (*Setaria vulpiseta* (Lam.) Roem. & Schult.), buffalograss (*Bouteloua dactyloides* (Nutt.) J.T. Columbus), sand dropseed (*Sporobolus cryptandrus* (Torr.) A. Gray), little bluestem (*Schizachyrium scoparium* (Michx.) Nash), sand lovegrass (*Eragrostis trichodes* (Nutt.) Alph. Wood); and forbs Illinois bundleflower

(*Desmanthus illinoensis* (Michx.) MacMill. Ex B.L. Rob. & Fernald), purple prairie clover (*Dalea purpurea* Vent.), and partridge pea (*Chamaecrista fasciculata* (Michx.) Greene).

Of the currently available commercial varieties of these native species that meet TxDOT (2004) and Texas Seed Law (TDA 1988) specifications allowing use in roadside plantings, only one species (Sabine Illinois bundleflower-Gulf Prairies and Marshes) originates from a south Texas ecoregion (Table 1.1). One additional species, Mason sand lovegrass, narrowly falls within the accepted ecotypic range of the far northern portion of the San Antonio District only.

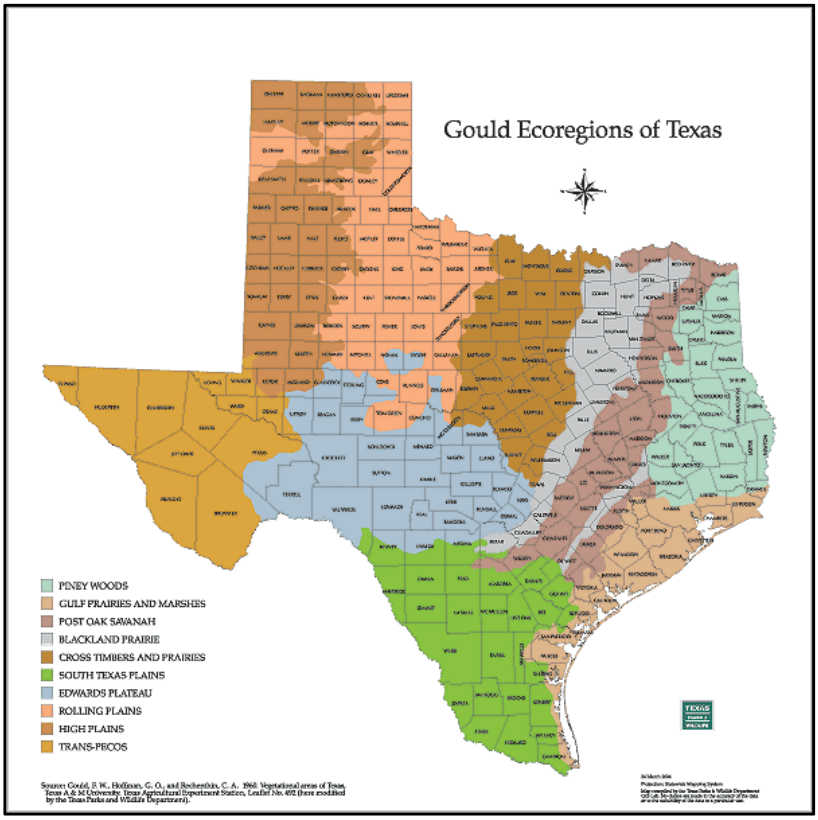

Figure 1.3. Map of Gould's (1969) Ecoregions of Texas, Courtesy Texas Parks and Wildlife Department.

Because of the poor performance of seed of these maladapted or non-ecotypic native seed mixture components, TxDOT continues to include exotic grass seed (i.e., buffelgrass, Lehman lovegrass, and Bermudagrass) in seeding mixes and specification to meet Federal vegetation cover mandates of the Clean Water Act (USEPA 2010). However, compliance with these Clean Water Act Provisions is in direct violation of the more recent Executive Order 13112 on Invasive Species (Clinton 1999), which directs government agencies to provide for the restoration of

native species along roadsides, and not authorize, fund, or carry out actions that are likely to cause or promote the introduction or spread of invasive species.

In order to make ecotypic sources of native seeds available for south Texas and meet both coverage and native species use requirements, Project 0-4570 South Texas Native Plant Restoration Project, was initiated in 2001. Goals of the project included collection of local seed ecotypes of native plants, evaluating and selecting collections of potential use by TxDOT, facilitating their production by local commercial seed growers, and finally ensuring ecotypic native seeds are available to end users such as TxDOT for reseeding projects in south Texas (Markwardt 2005).

Table 1.1. Origin of Native Seed Varieties Currently Specified for Use by TxDOT in Corpus Christi, Laredo, Pharr, and San Antonio Districts.

Common name	Commercial variety	Texas Ecoregion/other state of origin
Buffalograss	Texoka	Rolling Plains/Oklahoma, Kansas
Green sprangletop	Van Horn	Trans-Pecos, Mountains and Basins
Illinois bundleflower	Sabine	Gulf Prairies and Marshes
Little bluestem	OK Select Germplasm	Oklahoma
Partridge pea	Comanche	Rolling Plains
Plains bristlegrass	Stevan	High Plains/Arizona, New Mexico
Purple prairie clover	Cuero	Post Oak Savannah
Sand dropseed	Borden County Germplasm	Rolling Plains
Sand lovegrass	Mason	Edwards Plateau
Sideoats grama	Haskell	Rolling Plains

OBJECTIVES

The objectives of this research were to develop adaptable native seed mixes and effective revegetation strategies and techniques TxDOT can implement for right-of-way plantings in south Texas.

The specific tasks carried out during the course of the project were as follows:

- Selection of native species of interest to be developed for TxDOT use.
- Collection of native seeds from throughout the south Texas region for evaluation.
- Process and store collected seeds at the USDA NRCS E. “Kika” de la Garza Plant Materials Center for use and evaluation.

- Establish greenhouse and nursery plantings of collected seeds for evaluation and selection.
- Harvest seeds from nursery plantings for evaluation of seed quality characteristics.
- Test seed produced to screen for minimum levels of seed purity and germination in order to ascertain if evaluated materials are economically viable to produce.
- Increase seed of native species selected for release in order to provide commercial growers adequate seed for establishment of production fields, and to provide seed for experimental planting experiments.
- Conduct pilot experiments to develop planting methods for native seeds along highway rights-of-way using developed native seeds.
- Provide a comprehensive report of project activities, findings, and recommendations to TxDOT.

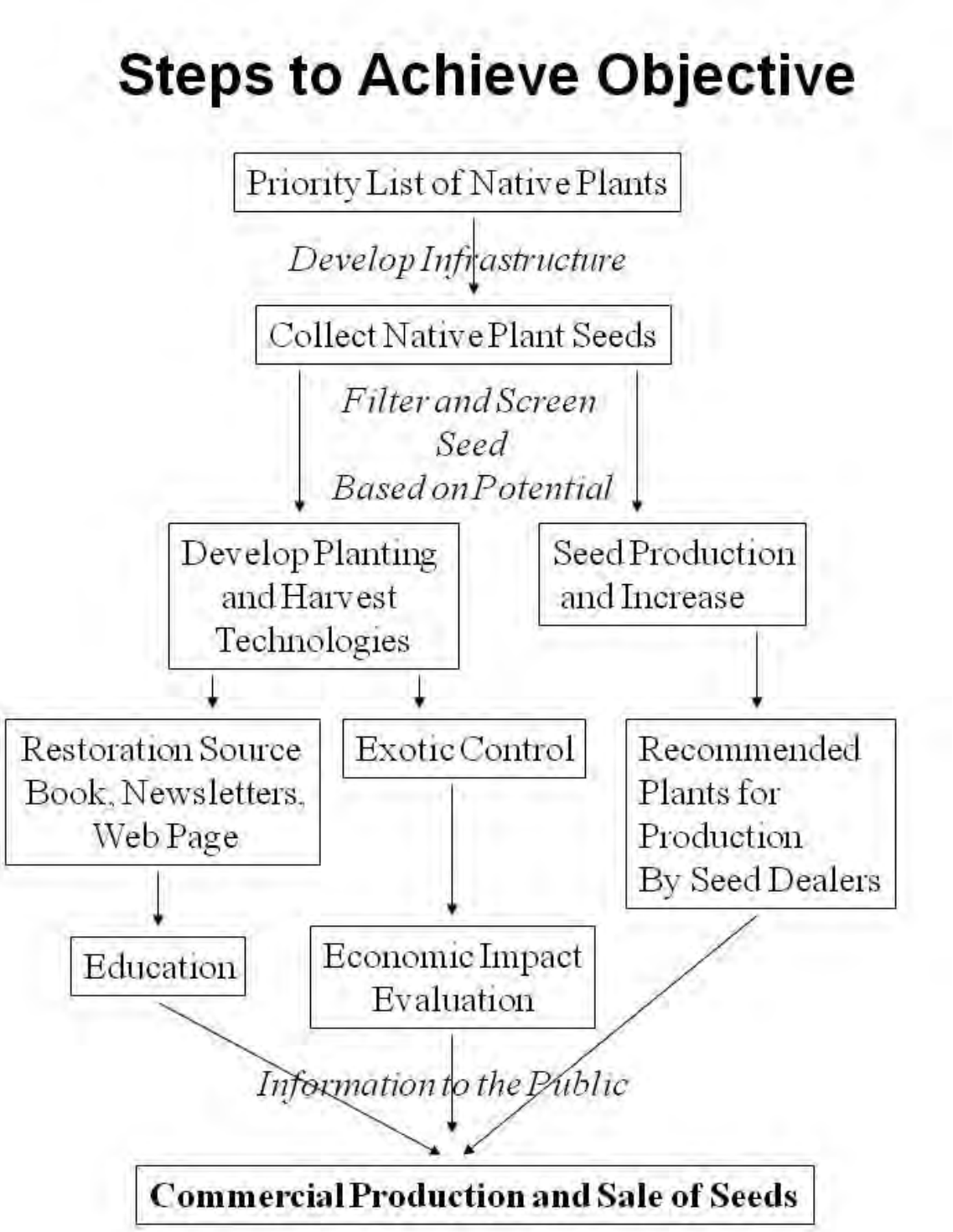

Figure 1.4. Original Schematic of Project to Provide Native Seed Sources for South Texas.

APPROACH

The project was conducted in three overlapping phases over a period of 10 years. Each phase of the project was carried out for each plant species considered; however Phases 2 and 3 began in later years of the project for some species, if environmental conditions (such as drought) prohibited the completion of Phase 1 in earlier years of the project.

1. Phase 1 consisted of efforts to collect, evaluate, and select promising germplasm of a variety of native species selected by the project technical committee as potentially useful for restoration and reclamation of south Texas rights-of-way by TxDOT.
2. Phase 2 involved the initial seed increase, advanced evaluation, and field testing of selected germplasm of each native plant species.
3. Phase 3 established larger seed increase plantings of species identified as acceptable for commercial release. After production-scale quantities of seed were produced, extensive release documentation was prepared, submitted for review and approval by the collaborating agencies, and formal release of seed was made to commercial producers.

CHAPTER 2: SELECTION OF SPECIES

Figure 2.1. Native Plants Growing along IH 37 near George West Texas.

Not all native plant species possess characteristics that make them desirable for use in roadside restoration. Furthermore, many species lack the genetic or environmental propensities to produce economical amounts of seed to make commercialization a viable option. Additionally, while some species may be useful for TxDOT, this potential market alone is not large enough to convince seed producers to provide products useable for just one demand sector (Williams pers. comm. 2010). So, while ecosystem restoration may be very successful when broadly diverse seed mixes representing all past plant community members of the site (Tinsley et al. 2005) are used, the implementation of such mixes, or the commercial production of the components (e.g., species) at the scale of seeding needed by TxDOT in south Texas districts (est. 3,000 acres/yr [Markwardt pers. comm. 2009]), is impractical.

In order to effectively develop seed sources of native plants for restoration within the framework of this project, a group of technical advisors was assembled to prioritize native plant species for collection, evaluation, and consideration of release in this project. This technical committee included a diverse group of natural resource managers, native plant experts, and seed producers (Table 2.1). From meetings of this group, a finite collection list of species was

developed, and species of greatest priority for the project were then sought by collectors (Table 2.2).

Figure 2.2. Native Grasses Such as Texas Grama Possess Characteristics that Are Desirable for Roadside Restoration, including: 1) Small Stature, 2) High Seedling Vigor, 3) Good Drought Tolerance, and 4) Ability to Grow in Shallow, Rocky, and Dry Soils.

Plant species selected for development in this project represent a variety of low growing (<5 ft mature height) grasses and forbs, including annuals and perennials, cool and warm season plants, and plants characteristic of a variety of habitat seral stages from early to late successional species. Species chosen have widespread distributions in south Texas and are found on a variety of soil series. Selections also took into account that species developed should have multiple demand sectors other than those specifically of TxDOT, including uses in rangeland, wildlife, conservation, and reclamation plantings. The potential to be able to economically produce seed of each species was carefully evaluated to ensure species collected, evaluated, and developed had a high likelihood of commercialization.

Once priority species lists were determined, information was sent to collaborating seed collectors, technical committee members, and student seed collectors were hired to begin collection of wild populations (germplasm) of the plant species from the south Texas region. A goal of two collections from each county in the project area (Figure 2.1) was set for collection. This was thought to provide representative genetic, climatic, and edaphic representation of each

plant species. The natural ranges of many species did not include the entire project area, so achievement of this objective was not possible in all cases.

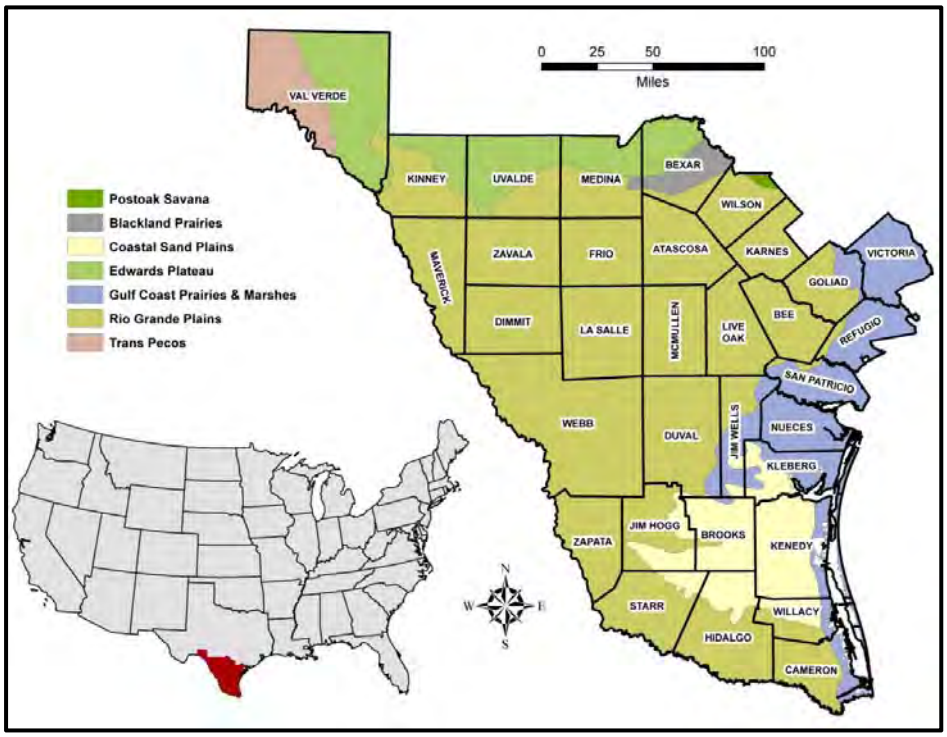

Figure 2.3. South Texas Native Plant Restoration Project Counties for Seed Collection.

Table 2.1. Original Project Technical Committee Responsible for Selection of Species for Project Focus.

Name	Affiliation	Category
Marc Bartoskewitz	King Ranch, Inc.	Private land manager
Paul Cox	San Antonio Botanical Gardens	Native plant expert
David Douget	Bladerunner Farms, Inc.	Turf/seed producer
Lynn Drawe, Ph.D.	Rob and Bessie Welder Wildlife Foundation	Native plant expert
Lavoyger Durham	El Tule Ranch	Private land manager
Jim Everitt, Ph.D.	USDA Agricultural Research Service	Native plant expert
Timothy E. Fulbright, Ph.D.	Caesar Kleberg Wildlife Research Institute	Academic researcher in restoration and wildlife
Vivian Garcia	USDA Natural Resources Conservation Service	Rangeland management specialist
Andres Garza, Jr.	Texas Soil and Water Conservation Board	Conservation program specialist
David Grall	Laborcitas Creek Ranch	Private land manager
C. Wayne Hanselka, Ph.D.	Texas AgriLife Extension-Corpus Christi	Rangeland management specialist
Patrick D. Larkin, Ph.D.	Texas A&M University-Corpus Christi	Academic researcher in plant genetics
John Lloyd-Reilley	USDA NRCS E. “Kika” de la Garza Plant Materials Center	Native plant expert
David Mahler	Environmental Survey, Inc.	Restoration specialist
Bill Nieman	Native American Seed	Seed producer
William R. Ocumpaugh, Ph.D.	Texas AgriLife Research-Beeville	Academic researcher in agronomy and forages
Gary Pogue	Pogue Agri Partners	Seed producer
Stan Reinke	USDA Natural Resource Conservation Service	Rangeland management specialist
David Riskind	Texas Parks and Wildlife Department	State land manager
Jimmy Rutledge	Texas Parks and Wildlife Department	Wildlife habitat management specialist
Lisa Williams	The Nature Conservancy	NGO land manager
Steve Windhager, Ph.D.	Lady Bird Johnson Wildflower Center	Restoration specialist
Larry Zibilske	USDA Agricultural Research Service	Academic researcher in agronomy
Rick Wood	Pape-Dawson Engineers, Inc.	Reclamation specialist

Table 2.2. Priority Species List for South Texas Native Plant Restoration Project.

Common name	Plant type/seral stage (early, mid, or late)	Rank 1-5 (1=highest priority for collection)
Arizona cottontop	Grass/mid	1
Plains/streambed bristlegrass	Grass/mid	1
Hooded windmillgrass	Grass/early	1
Shortspike windmillgrass*	Grass/early	1
Pink/whiplash pappusgrass	Grass/late	1
Halls panicum	Grass/early	1
Brownseed paspalum	Grass/late	1
Sideoats grama	Grass/late	1
Green sprangletop	Grass/early	2
Slim/rough tridens	Grass/mid	2
Little bluestem	Grass/late	2
Silver bluestem	Grass/mid	2
Rio Grande bristlegrass	Grass/mid	2
Red grama	Grass/early	2
Wrights threeawn	Grass/early	2
Purple threeawn	Grass/early	2
Texas panicum	Grass early	3
Hairy grama	Grass early	3
Texas grama	Grass/mid	3
Slender grama	Grass/early	3
Common curly mesquite	Grass/late	3
Multiflowered false rhodesgrass	Grass/late	3
Plains lovegrass	Grass/early	3
Orange zexmenia	Forb/late	1
Awnless bush sunflower	Forb/mid	1
Engelmann daisy	Forb/late	1
Redseed/Hookers plantains	Forb/early	2
Rio Grande clammyweed	Forb/early	3

*****shortspike windmillgrass was not collected since adequate collections were already present in the Plant Materials Center inventory.

CHAPTER 3: SEED COLLECTION

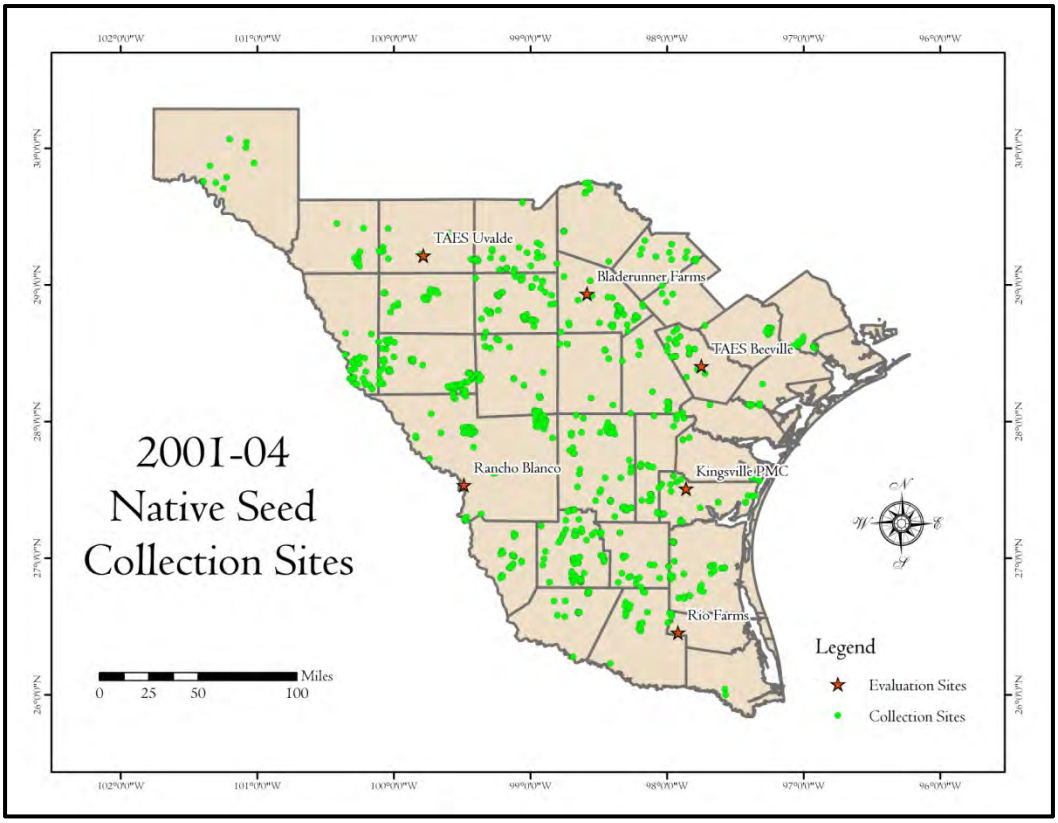

Figure 3.1. Native Seed Collection Sites for the South Texas Native Plant Restoration Project.

Beginning October 2001, project personnel obtained wild seed collections of target plant species. From 2001–2004, 1,032 collections of the target species were obtained. Some species were collected more frequently because of common occurrence or distribution across the region and others may have been collected in higher numbers simply by random occurrence during collection efforts. Populations of some species were wholly absent from large areas of the project region of focus, likely due to past management practices including brush management, overgrazing, or a history of farming. The Lower Rio Grande Valley was one such region where relict stands of native plant species of interest are essentially gone from the landscape.

At each collection site, collectors randomly traveled across the accessible landscape by foot or vehicle to locate population of each plant species of interest. Typically, no more than two collections of the same species were made at a general collection site, such as a ranch, or highway right of way within a single county. When collecting on extremely large ranches (>10,000 acres), more collections were often obtained, especially if distinguishing characteristics

between possible collection sites were apparent. An example would be widely divergent soil series or textures, or different land use histories of separate collection sites. Often a seed collection from a species was bulked from throughout a ranch or land management unit and identified as a single collection.

Figure 3.2. Project Seed Collector Obtaining Seeds of Pink Pappusgrass in Webb County, Texas.

For each species of interest encountered with ripe seeds, collectors obtained seed from as many plants as possible to maximize genetic diversity of the seed collection. Seed was hand stripped from the plants and placed in paper lunch bags (bag size #s 5, 6, or 7). Collection bags were immediately labeled with the collection date, common name of the species, name of the collection site, soil series name (if available), soil texture of the site, specific locality of the collection (ranch or place name, highway number, etc.), and finally Global Position System (GPS) coordinates of the collection site were recorded. Additional information was also recorded such as exceptional plant or population characters, competitive ability with exotic vegetation in the area, or observations of regeneration characteristics. Following the field collection, all collection information was transferred into an Excel database for cataloguing and organization, and a separate collection form was filled out with the collection information and stapled or otherwise attached to the original bag of seed. Once field-processed in this manner,

seeds were delivered or shipped to the USDA NRCS E. "Kika" de la Garza Plant Materials Center in Kingsville for further processing (Chapter 4).

SUMMARY OF SEED COLLECTION

Grasses made up 90 percent of the 1,032 seed collections obtained for the project. Grass seeds are typically easier to collect; the seeds remain attached to the plants longer; and grass seeds are less likely to be depredated by wildlife and livestock. Collection totals were highest in 2002 and 2003, in part because of greater seed collection effort during those periods. However, 2002 was a high precipitation year in south Texas, which facilitated good native seed production of a number of native species. Seed collection totals by year and plant type are given in Table 3.1. Please note that because of the high priority placed on grasses by the project technical committee, the collection list was comprised of 21 species of grasses and five species of forbs.

Table 3.1. Summary of Seed Collections by Plant Type and Year.

Year	Grasses		Forbs		Annual total
	# of collections	% annual total	# of collections	% annual total	
2001	50	96	2	4	52
2002	567	92	52	8	619
2003	246	90	28	10	274
2004	65	75	22	25	87
Total	928	90	104	10	1032

Seed collections were sought throughout the year, to maximize genetic diversity of the collections obtained. Since a mixture of warm and cool-season plants were present on the list, some species obviously matured at divergent times of the year. However, we present data on month of collection for the project, as a good reference to best periods of the year for collection efforts for future projects, or for use by others interested in similar work in south Texas (Table 3.2). The cyclical nature of the south Texas climate and sporadic annual distribution of rainfall requires multiple years of seed collection in order to obtain representative collections of even a small group of native species from an area the size of south Texas. In general, over the four years of collection, the months of May, June, July, August, October, November, and December were productive seed collection months.

Table 3.2. Percent of Annual Total of Seed Collections Obtained by Month 2001–2004.

Month	% Seed collections obtained by month			
	2001	2002	2003	2004
January	-	0	3	0
February	-	0	0	0
March	-	0	0	1
April	-	2	0	7
May	-	22	18	8
June	-	8	27	15
July	-	5	10	33
August	-	29	9	1
September	-	5	0	0
October	30	7	6	0
November	34	9	19	32
December	36	13	8	0

Table 3.3. Summary of Seed Collection Sites by Type, 2001–2004.

Site type	Number of collections	% of total
County road rights of way	64	6
Farm-to-market road rights of way	49	5
Federal lands	24	2
Non-government organization lands	24	24
Private land	777	75
State lands	44	4
Total	1,032	100

The most productive seed collection locations were private lands, namely large private ranches. Seventy-five percent of collections were obtained from private lands. County road rights-of-way were a distant second, with 64 collections obtained from these areas. A number of other types of seed collection sites (e.g., federal and state owned lands) were visited during the project; however most yielded few collections for the project.

Figure 3.3. Silver Bluestem Was the Species Most Frequently Collected in the Project.

Silver bluestem was the species collected most frequently during the project. Other common grasses readily collected included hooded windmillgrass, little bluestem, and pink/whiplash pappusgrass. Orange zexmenia and awnless bush sunflower were the forb species most commonly collected.

Table 3.4. Summary of Collections by Species, 2001–2004.

Species common name	Number of collections
GRASSES	
Silver bluestem	102
Hooded windmillgrass	82
Little bluestem	81
Pink/whiplash pappusgrass	76
Slim/rough tridens	60
Multiflowered false rhodesgrass	59
Plains/streambed bristlegrass	54
Red grama	50
Arizona cottontop	49
Sideoats grama	48
Halls panicum	46
Curly mesquite	39
Rio Grande/Reverchons bristlegrass, Knotgrass	35
Hairy grama	35
Purple threeawn	27
Texas grama	25
Wrights threeawn	24
Brownseed paspalum	15
Green sprangletop	11
Slender grama	9
Texas panicum	1
Total grasses	928
FORBS	
Orange zexmenia	34
Awnless bush sunflower	28
Redseed/Hookers plantain	25
Engelmann daisy	11
Rio Grande clammyweed	5
Total forbs	104
ALL SPECIES	
Total forbs and grasses	1032

CHAPTER 4: SEED PROCESSING AND STORAGE

Figure 4.1. Cleaning Native Seed Collections at the USDA NRCS Plant Materials Center in Kingsville.

Once collections were obtained from the field they were air dried under ambient conditions. Collections were then sent to USDA NRCS E. "Kika" de la Garza Plant Materials Center (PMC). Upon receipt of collections by the PMC, their staff assigned each collection with a unique nine-digit accession number. This accession number was used from this point forward to identify the collection. The collection information was then entered into the nationwide PMC accession database.

After accession numbers were assigned, staff of STN and the PMC began cleaning collections so that actual seeds were separated from the original material collected. Chaff, stems, leaves, and other non-seed materials were then discarded. Methods used to clean seed from litter or inert materials in collections included hand separation, separation using various screens, seed blowers, fire, and hand stripping. Selections of each species were evaluated through this process for general seed fill, and if no viable seeds could be found, the collection was discarded. Approximately 1–2 percent of collections were determined to be non-viable during the cleaning process.

Seeds of some species could not reliably be cleaned from stems and trash. Plants whose seed could not be cleaned to an acceptable level of purity (e.g., seed making up 10–20 percent by weight of material) were noted. These species were identified as potentially problematic for production by commercial producers, as 100 lb of pure seed would require as much as 1,000 lb of inert material harvested, transported, dried, stored, and bagged. This would result in extremely high seed costs to consumers. Some species, such as purple and Wrights threeawn for example, were specifically not worked with in detail in this project because of purity considerations.

Figure 4.2. Many Native Grass Species such as Arizona cottontop (above) Have Seeds Covered in Dense Pubescence (e.g., "fluffy seeds") that Can Be Difficult to Clean and Process.

Other species, such as Arizona cottontop, presented difficulties in cleaning. For these species, various cleaning techniques were conducted to determine if it was possible to clean or process the seed sample to a degree in which seed would be "mechanically plant-able." If no method for cleaning was determined that would facilitate mechanical planting of the species, then further selection or evaluation work with collections of that species was limited. Examples again included purple and Wrights threeawn. For Arizona cottontop, seed coatings were determined to be an economically and practical method of processing seeds so that they could be mechanically planted; thus work with this species was continued.

Once cleaned and processed seeds were weighed and placed into PMC Program storage envelopes that included both the accession number and all collection information. These envelopes were stored in climate (temperature and humidity) controlled seed vaults at the PMC to preserve the seed and provide cold stratification necessary for germination of many species. Viability of the collections for use throughout the project was assured by these storage conditions.

For collections of species where no information regarding seed quality, germability, or germination, dormancy ratios were available and initial laboratory or greenhouse trials were conducted. These trials were not a true evaluation of quality characteristics of the species but did give an indication of the variation among the accessions for seed quality characteristics. Some species, notably common curly mesquite and a complex of bristlegrasses (Reverchons, Rio Grande bristlegrasses and knotgrass) showed almost no propensity for viable seed. Therefore these species were not evaluated beyond these tests. Conversely, evaluation of slim/rough tridens, redseed, and Hookers plantains showed a high amount of variation in seed quality characteristics among accessions. These species were then targeted for selection of the high seed quality accessions or ecotypes, which were then evaluated for other desirable traits.

Figure 4.3. Extensive Research and Lab Trials Were Necessary to Determine Appropriate Seed Cleaning Techniques for Grasses like Hairy Grama (above). Many Species Considered in This Project Had Not previously Been Worked with by Scientist.

CHAPTER 5: NURSERY AND GREENHOUSE PLANTING

Figure 5.1. Preparing Native Plant Transplants for Planting in an Evaluation Plot at Rancho Blanco near Laredo, Texas.

Once suitable numbers of local collections of a species were obtained, we proceeded to grow seedlings from each accession in the greenhouse for transplanting into filed nurseries for initial evaluation of the respective species. For each species we evaluated, commercially available materials of the species, or previous releases of the species were included in each evaluation for comparison. Field plant nurseries (hereafter referred to as "evaluation plots") were utilized throughout the project area (Figure 5.1). Greenhouse facilities at Kingsville (TAMUK Campus and the USDA NRCS Plant Materials Center) (Figure 5.2), as well as at the Texas AgriLife Research Station in Beeville were utilized in this portion of the research. Methodology for each phase of the project is given below.

GREENHOUSE PLANTINGS

Plantings of warm season plants for evaluations were started in multi-cell flats in the greenhouse in late November of the year preceding installation of the evaluation experiment. For initial evaluations of most species 50–100 plants/accession were produced. Planting trays were filled with a commercial potting mix and planted with ~10 seeds per cell of the desired

accession. Trays were labeled with the 9-digit USDA NRCS accession number for identification. All trays were hand watered to promote emergence and growth of the seedlings. Once seedlings were mature enough to withstand ambient conditions outside the greenhouse, flats were placed in a shade house to harden-off the plants for field planting.

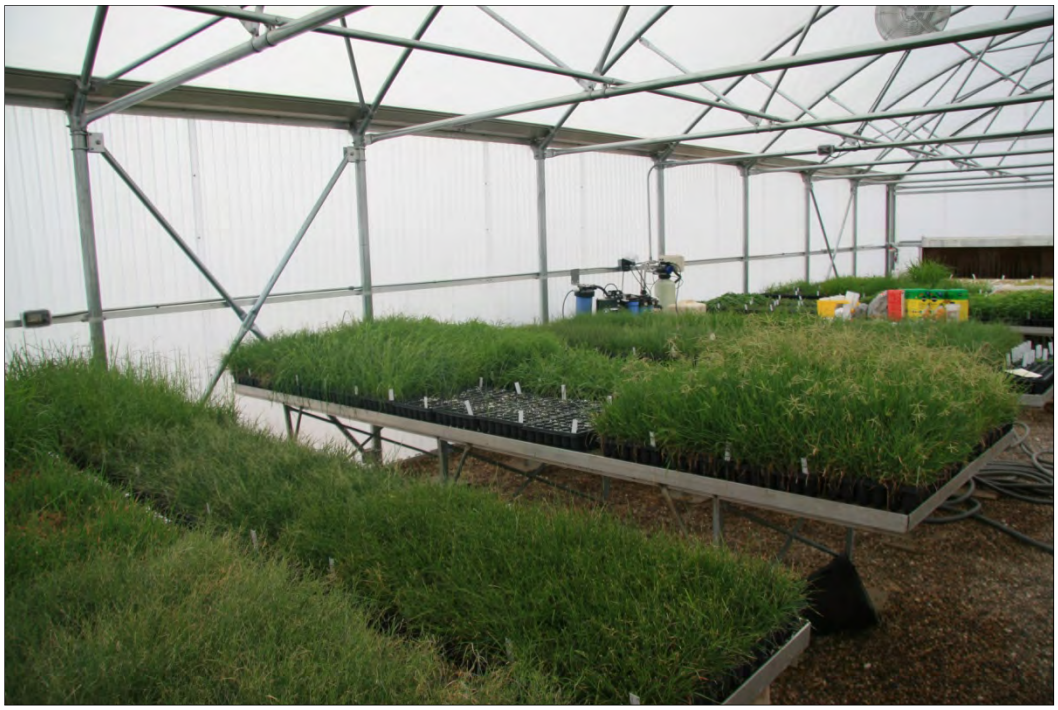

Figure 5.2. Native Plant Transplants for Evaluation Plots Being Produced in the Project Greenhouse.

EVALUATION PLOT DESIGN

Evaluation plot plantings at multiple growing locations were desired for all plant selection experiments. This was done in order to avoid selection bias by site. A minimum of two evaluation locations were used for each species, but in most cases 3–5 sites were utilized (Figure 5.3). Evaluation locations were selected to be representative of sites throughout the natural distribution range of the species being evaluated, as well as representative of potential use regions of the plant material. Typical plantings were arranged in a randomized block design for each evaluation location.

Figure 5.3. Evaluation Plot Planting of Slim Tridens at Texas AgriLife Research Station Uvalde.

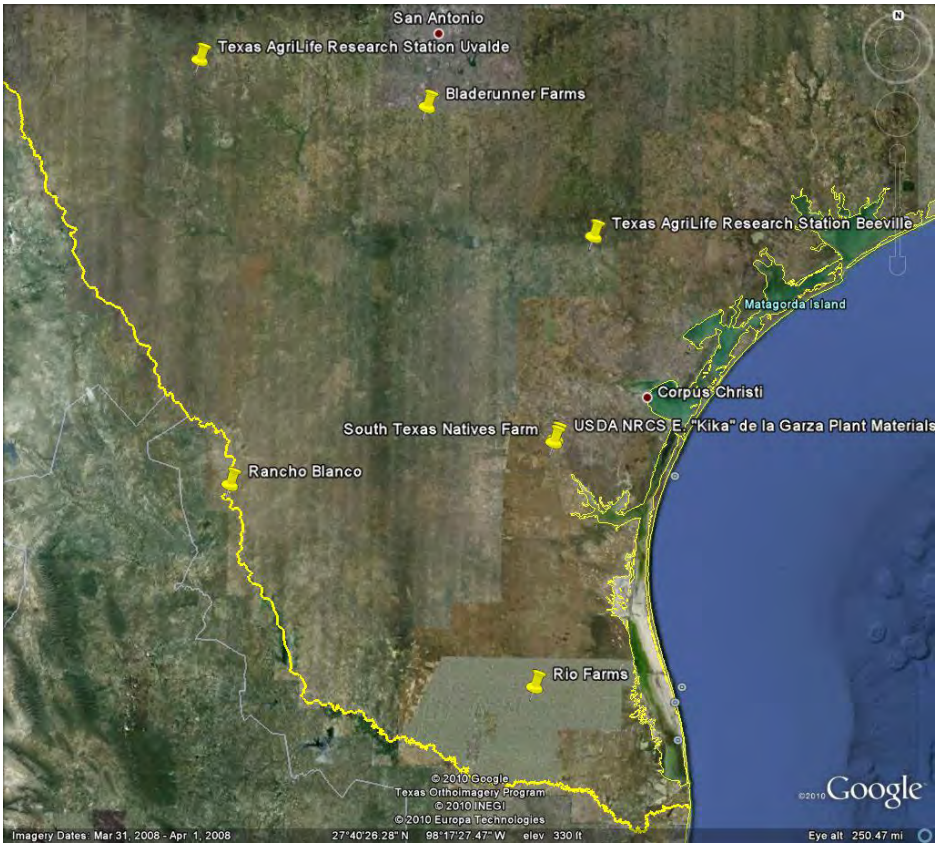

Figure 5.4. Map of Plant Evaluation Locations Utilized in the South Texas Native Plant Restoration Project. Courtesy Google Earth.

Each evaluation location utilized a split-plot design so that there were two replications (blocked) of each accession planted at each location. Typically this included two completely randomized sets of plots, each containing 10 transplants of each accession. Transplants were planted in 30–36 inch rows depending on equipment available at each location, with 1–2 ft spacing among individual transplants in a row depending on mature plant size of the species being evaluated. Larger grasses were planted at the 2 ft interval whereas small stature plants were planted at 1 ft intervals. Plots of each accession were separated by 5 ft space between the tenth plant of one accession and the first plant of the neighbor accessions. Plots within a replication were located on uniform sites to minimize variability within replications at each evaluation site. Soil series and surface textures of the evaluation sites are given in Table 5.1.

Table 5.1. Soil Series and Texture of Evaluation Plots Utilized in the Project.

Evaluation site name	Soil series and texture
South Texas Natives Farm	Cranell sandy clay loam
USDA NRCS E. "Kika" de la Garza PMC	Victoria clay
Rancho Blanco	La Gloria silt loam
Texas AgriLife Research Station-Beeville	Parrita sandy clay loam
Texas AgriLife Research Station-Uvalde	Uvalde silty clay loam
Rio Farms	Delfina fine sandy loam
Bladerunner Farms	Miguel fine sandy loam

Plots were prepared for planting by multiple disking treatments. Planting beds were used where necessary depending on soil series, and to facilitate irrigation and maintenance. Bedded rows were utilized at Rio Farms, Rancho Blanco, STN Farm, the PMC, and Texas AgriLife Research Station-Uvalde (TARS-U) (Figure 5.1). Transplants were installed by hand or by use of mechanical transplanters pulled by small tractors. Accessions were identified by the 9-digit accession number or a sequential number corresponding to the accession number. Plot maps were made by hand in the field and subsequently copied into Microsoft Excel (Figure 5.2). Immediately following planting, pendamethelin herbicide (trade name Prowl) was applied to prevent weed seed germination. Following herbicide application, supplemental irrigation was applied to ensure transplant establishment. Plots at Rancho Blanco, TAR-U, and Rio Farms were flood irrigated, and those at Bladerunner Farms and Texas AgriLife Research Station-Beeville (TARS-B) were sprinkler irrigated. Following initial irrigation, weedmat was installed on most sites to prevent weed growth between rows of plants. Weeds that emerged within

planted rows were controlled by hand hoeing or selective use of herbicides. Herbicides used most frequently included glyphosate (for blank spaces between transplants), 2-4, D (for broadleaf weeds in grass plantings), and Fusillade (for grass weeds in forb plantings). At the completion of the growing season all plots at each evaluation location were mowed, and the thatch raked and removed to facilitate new growth in the following evaluation year. Pendamethelin herbicide was reapplied to help control weeds after raking in each year. Supplemental irrigation was provided at all plots throughout year 1 to promote maximum plant growth for evaluation. Irrigation was discontinued thereafter.

	9088987	9090589		9088992	9090318
	9088608	9090548		9088925	9088989
	9089182	9088951		9088609	9090548
9088831	9090318	9090553	9088987	9090380	9088825
9088992	9090290	9088968	9090360	9090290	9088927
9091865	9088925	9088989	9088780	9088608	9089182
9089060	9090707	9088927	9088903	9088548	9089060
9088779	9088809	9088609	9088778	9088968	9088779
9088903	9090380	9088562	9090707	9090589	9088831
9088778	9088780	9088825	9088809	9088951	9088804
9090360	9088548	9088804	9088562	9090553	9091865
35	**34 33**	**32**	**31**	**30**	
		4-flower trichloris			

Figure 5.5. Example Plot Map of 4-Flower Trichloris Accessions Evaluated at Rancho Blanco.

EVALUATION PLOT DATA COLLECTION

Data were collected monthly for each evaluation plot in year 1 and bi-monthly thereafter. Evaluations consisted of visual rankings of plant performance. These evaluations were conducted utilizing multiple trained evaluators for each evaluation. Characteristics evaluated included survival, plant vigor, foliage density, uniformity, development stage, seed production, forage production, plant height, and comments. A numerical ranking system was used to record observations for most characteristics, where a value or score of 1 was given to the superior performing accession for each characteristic at the site, and a value of 9 given to the poorest performing accession at the site. For survival, values were expressed as a percent of surviving plants at the evaluation date, based on a plant count obtained between 30–60 days post-planting. An explanation of each evaluation category is given below.

Figure 5.6. Project Employees Observing and Recording Seedhead Characteristics of an Arizona Cottontop Accession at the Rio Farms Evaluation Plot.

Survival

Survival was expressed as the percent of transplants surviving at each evaluation date, based on a count of seedlings that survived for a minimum of 30 days after transplanting. Survival was based on the post-planting count because early transplant mortality can be caused by factors unrelated to plant adaptability or performance at the evaluation site (i.e., low-quality transplants, poor planting techniques, or insufficient irrigation). By basing survival counts on 30-day post planting counts, we hoped to avoid biased estimates of mortality caused by planting and transplant factors. Individual plants were carefully identified as those transplanted and not volunteer plants. Volunteer plants were controlled for by use of pre-emergence herbicides that limited volunteer plants from seed. To help further distinguish which plants were transplanted from those that may have volunteered, transplants were carefully spaced in each evaluation plot in a linear row at a specific interval from one another.

Plant Vigor

Plant vigor was a cumulative expression of the performance of each accession. Factors such as foliage color, degree of chlorosis, incidence of disease, overall rate of growth, and vegetative spread were consider in vigor rankings.

Foliage Density

Foliage density rankings related to the closure or lack of closure of canopy of the plants. Criteria such as ability to fill spaces between plants, width of leaf canopy, and density, width, and length of leaf blades were considered.

Uniformity

Uniformity of the accession was an important consideration for later selection, production, and commercialization of any accession. Uniformity was an indication of the heterogeneity or homogenous nature of the plants of the accession. Accessions that were highly uniform (all plants had near-identical characteristics) were given a ranking of 1, since this is a desirable characteristic from a seed production standpoint, and accessions with highly variable plants were given higher numerical rankings.

Development Stage

Development stage was an important evaluation character for the selection of accessions for multiple-accession blend releases. Accessions could only reasonably be grown together in mixed accession releases in later seed increases or commercial seed production settings if they grew and produced ripe seed at the same time on a common site. Development stage rankings were different than other rankings in that scores of 1–9 corresponded to various growth stages of the respective plant species. For grasses, rankings were as follows: 1=ripe seed present on plants, 2=immature seed present on plants, 3=flowering stage, 4=boot stage (reproductive stages not emergent from foliage), 5=stem elongation phase, but prior to seedhead formation, 6=vegetative stage, no reproductive stems emerging from crown, 7=immature vegetative stage, 8=post transplant stage with new growth, and 9=seedling or transplant stage. Cumulative analysis of development stage data over an evaluation year indicating a low-mean score in this

category could be interpreted as representative of accessions capable of producing seed throughout the year and potentially having high seed yields, a desirable characteristic.

Seed Production

Seed production rankings were based heavily on three criteria: 1) density and number of seedheads present on the accession, 2) size (typically length) of individual seedheads, and 3) density of spikelets present on the seedheads. Actual measures of seed produced (weighed in grams) were occasionally taken for seed production rankings, especially in later stages of evaluation of a species.

Forage Production

Forage rankings were an estimate of the biomass produced by each accession. Occasional rankings were based on actual estimates obtained by clipping and weighing biomass samples from the accessions. High biomass production was typically a secondary consideration for selection.

Plant Height

Plant height was evaluated in order to find accessions that could be combined in multiple accession blend releases and to find accessions that could be mechanically harvested together in multiple accession blend seed fields. Actual measurements in centimeters were occasionally taken in order to quantify plant height, especially in later stages of an evaluation.

Comments

A comments section was included on evaluation sheets for inclusion of evaluators remarks about accessions. Cumulative analysis of the accessions, such as noteworthy performance in an evaluation category could be recorded; comments commonly included observations regarding diseases, fungi, and pests impacting the accession. Notes regarding external influences on plots were also made in order to provide information that might explain temporary sources of variation or damage to a plot.

ANALYSIS OF EVALUATION PLOT DATA

Evaluation data were analyzed by a number of methods. For actual measurements, analysis of variance (ANOVA) statistical procedures were used. For visual rankings and other nonparametric data, simple means by site and year were calculated and used to separate superior accessions from poor performing accessions. Means were calculated for all accessions at each site, and accessions with better than mean performance in the greatest number of categories at each evaluation site were those considered for selection. All data were considered by year and by site in the selection process.

CHAPTER 6: SEED HARVEST

Figure 6.1. Collecting Seed from an Evaluation Plot.

EVALUATION PLOT SEED COLLECTION

Throughout each evaluation year, seeds from all accessions were collected for testing and quality analysis. In the first year of evaluation, seeds were collect when ripe from all accessions at each evaluation location by accession. Seed from both replications of each individual accession were combined for testing. Efforts to collect seed from each of the 20 plants present at the evaluation sites were made. Collections were made by hand stripping the ripe seeds from the seedheads and placing seeds into paper bags with the date of the collection, respective accession number, and site name. Seeds were stored in ambient conditions and allowed to air dry following collection. Germination tests were conducted a minimum of 3 months after field collection to allow a period of after-ripening needed by many seeds in order to germinate.

CHAPTER 7: SEED TESTING

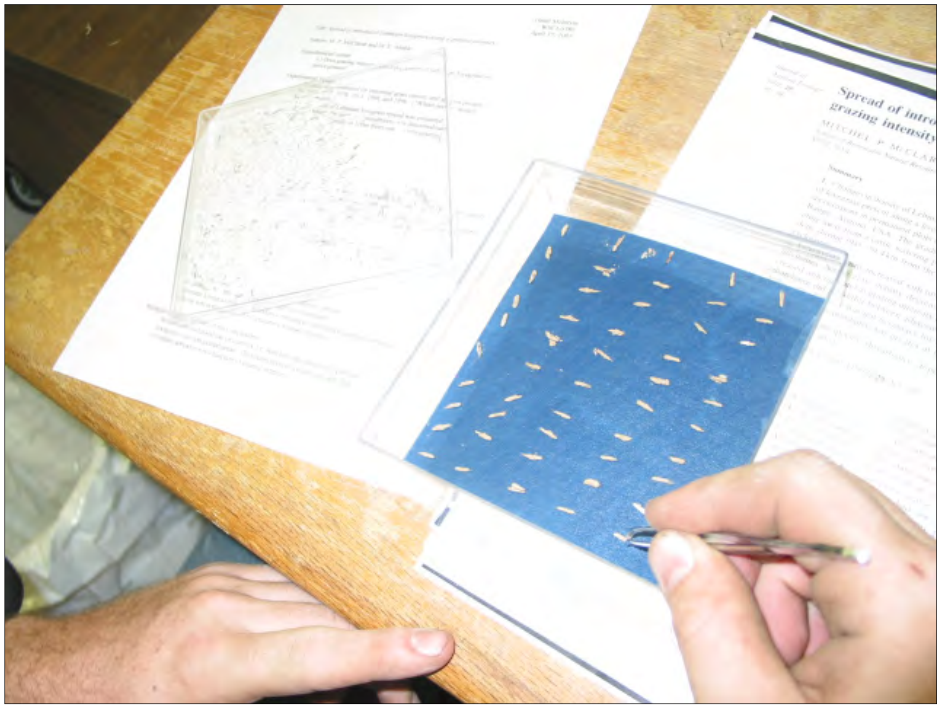

Figure 7.1. Counting Seeds and Placing Them into a Container for a Germination Trial.

Following collection and after-ripening, seeds of each site-accession were thoroughly mixed, and samples were drawn and hand counted for use in germination trials. These experiments were conducted using a diurnal growth chamber with 12 hrs light at 85°F to simulate daytime conditions, and 12 hrs dark at 68°F to simulate nighttime conditions. For most tests, 4–100 seed replications from each accession were included. Occasionally because of low seed production of some species, 50 seed replications were required. After placing seeds in labeled Petri dishes wetted with deionized water, counts of seeds germinated were made every other day for 30 days, beginning on day 3 after installation of the experiment. Tetrazolium tests were conducted by outside laboratories when needed to assess species with high seed dormancy. In year 2 and beyond, specific germination tests by harvest date were conducted. These tests provided an indication of best seed harvest dates for later seed increase and commercial production. The same germination test methodology was used for these tests. From these tests, rankings of percent active germination could be made by accession for consideration in the selection process. Consistency of germination from test to test was considered a desirable character of an accession. Other information obtained from these tests included measures of time of initiation of germination and time to total germination.

Figure 7.2. Germination Trays in the Growth Chamber for an Experiment.

ANALYSIS OF EVALUATION PLOT SEED GERMINATION DATA

Mean germination of seed from each accession was calculated by site following germination tests. Also calculated was mean germination of all accessions by site. Accessions with greater than the mean germination for the species were noted and considered for release. Time of germination was calculated as number of days to 10 percent of total germination, and time to total germination was calculated as number of days to 50 percent of total germination.

CHAPTER 8: SEED INCREASE

Figure 8.1. Seed Increase Fields of Native Grass Selection at Rio Farms in the Lower Rio Grande Valley, Texas.

Following analysis of seed tests and evaluation plot data, selections of the best performing accessions were made. These accessions were then grown for seed increase for further testing, release, and distribution to commercial seed growers for production.

In all cases, seed increases were initiated with seed or vegetative material from the original plant population of each chosen accession to ensure the genetic integrity of the future release. In most cases, seed from the original field collection was used to begin increase of the accessions. In cases where the original seed collection was used in its entirety in the evaluation phase, mother plants from the evaluation plots were dug, transplanted to isolated plots, and used to produce seed for use in seed increases.

Seed increase plots were isolated from other plots of the same species. Often multiple species were being increased at one time, so several seed increase plots were planted in an area, so long as only one accession of a given species was located in one area (Figure 8.1). A distance of 900 ft was considered adequate isolation for all species.

Figure 8.2. Phase I Seed Increase of a Selection of Pink Pappusgrass.

Increases of most accessions required a two-phase process conducted over 2 years. In phase 1, a small plot of 50–100 plants of the accession was established by transplants. Throughout year 1, this plot was harvested intensively, and then this seed was used in year 2 to produce additional transplants for establishment of a larger field of typically 5,000 plants, which would produce enough seed of the accession for release to a commercial grower. Species-specific yields dictated these seed increase plot sizes.

Seed increase plots and fields were utilized at a number of locations throughout the project. But the majority of increases were installed at Rio Farms in the Rio Grande Valley of South Texas.

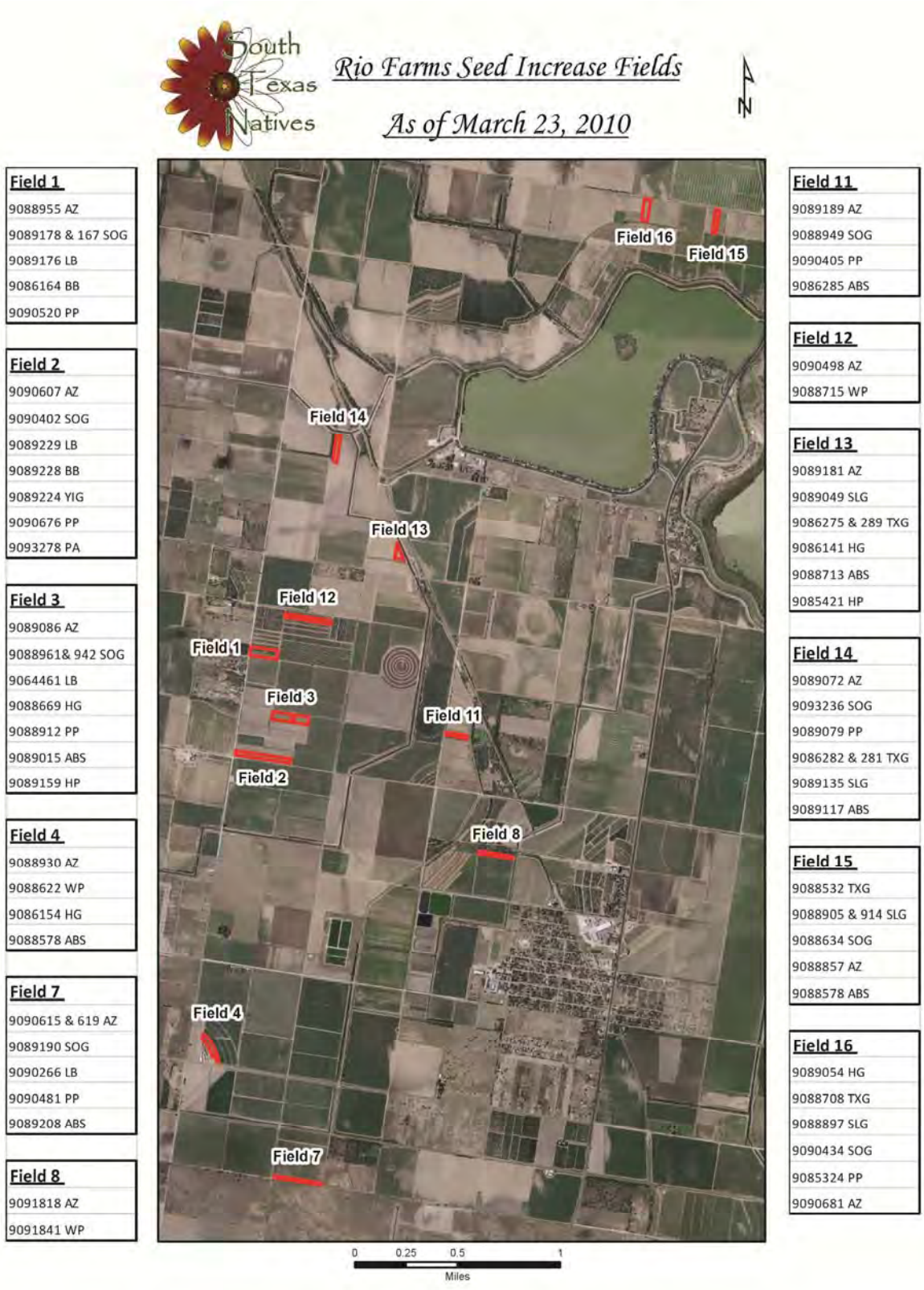

Figure 8.3. Seed Increase Field Map of Rio Farms, 2010.

CHAPTER 9: ESTABLISHMENT METHODS

Figure 9.1. Installing a Native Seed Establishment Method Experiment in South Texas.

A variety of experimental plantings were made throughout the course of the project to determine best establishment methods for each species and mixtures of species. Planting locations included highway rights of way, experimental field settings, and private ranchlands. Establishment methods were studied using a rigorous experimental protocol for all plantings, so that data from the various experiments could be evaluated and compared accordingly. Our establishment methods and experimental design are outlined below.

Site Inventory

Each planting site was evaluated prior to disturbance or site preparation. Detailed data sheets were completed with information including GPS coordinates, site history and present state, and soil series and texture. Whenever possible, presampling of the existing vegetation was conducted to include 3–100 point step-point transects, and semi-permanent photo-point markers were installed and initial photographs were taken.

Site Preparation

Site preparation by site varied according to the establishment method being studied. For all experiments detailed inventories of site preparation methods and chronology were recorded.

Seed Mixture Preparation

All seeds used in establishment method experiments were tested for germination, purity, dormancy (TZ tests), and noxious/invasive weed seed by third-party laboratories. Based on result of tests, seed mixtures were composed according to percent pure live seed (PLS). Each replication of each planting in an experiment was weighed and mixed separately.

Figure 9.2. Small-Plot Establishment Method Study after Installation.

Planting Equipment Calibration

Using the seed mixture specified, seed drills or broadcast planting equipment was calibrated using standard shop calibration techniques. Calibration was conducted using three replicated measures following each adjustment, followed by an additional replicate of three measures once the target rate was achieved as a check. Variances of ±10 percent of the desired rate were accepted because of limitations to planting equipment metering.

Planting Methods

All replications of each planting were installed on the same day if possible. Drill or broadcaster travel was consistent among replications. Between planting replications the drill or broadcaster was cleaned with a vacuum to prevent seed from one replication being accidentally planted in the following plot.

Evaluation and Data Collection

Data on plant performance were collected at 30 days post-planting and biannually in late spring and late fall each year of the experiment. Data collection methods included a minimum of 3–100 point step-point transects, and 25 to 100 0.25 m^2 frames used to estimate percent cover and or seedling/plant density of the seeded species. Data were evaluated using standard statistical procedures.

Figure 9.3. August 2008 (L) and June 2010 (R) Photographs of an Establishment Methods Experiment in Duval County Texas, Showing Excellent Performance of Native Seed Sources.

Figure 9.4. Native Grasses Growing along US HWY 77, 4 Years after an Establishment Methods Experiment.

Figure 9.5. Slender Grama (Front), Plains Lovegrass (Center), and Shortspike Windmillgrass(rear) in the US HWY 77 Median, 4 Years after an Establishment Methods Experiment.

CHAPTER 10: WORK SUMMARY BY SPECIES

Figure 10.1. Multiple Species Evaluation Study at Rio Farms in the Lower Rio Grande Valley of South Texas.

Chapter 10 gives a bulleted summary of the work performed from collection, through evaluation, to release as applicable for each plant species. For more information for released varieties, please see Appendixes A, B, and C. Unless different from methods described in Chapter 9, evaluation, experimental design, procedures, and analysis are not described in detail. Number of collections evaluated includes project collections and collections of the USDA Plant Materials Program that were available for evaluation.

Hooded Windmillgrass (*Chloris cucullata*)

- 142 collections were evaluated.
- Evaluation locations were the Plant Materials Center in Kingsville (PMC), Texas AgriLife Research Station Beeville (TARS-B), Rio Farms (RF), and Texas AgriLife Research Station-Uvalde (TARS-U).
- A single accession was chosen for release because of unique plant characteristics (e.g., a stoloniferous growth habitat beneficial for roadside plantings) and superior seed quality.
- Seed quality and production attributes were evaluated in PhD projects.

- Work resulted in release of Mariah Germplasm hooded windmillgrass
- Commercial seed is produced by Douglass W. King Seed Company.
- Performance in field plantings suggests variety is a rapid establishing grass cover on coarse textured soils.

Shortspike Windmillgrass (*Chloris x subdolistachya*)

- 42 collections were evaluated.
- Evaluation locations were the PMC, TARS-B, RF, and TAR-U.
- A single accession was chosen for release because superior seed quality and dense cover and foliage characteristics.
- Seed quality and production attributes were evaluated in PhD projects.
- Work resulted in release of Welder Germplasm shortspike windmillgrass.
- Commercial seed is produced by Turner Seed Company and Pogue Agri Partners.
- Performance in field plantings suggests variety is a rapid establishing grass cover on fine textured soils.
- Welder Germplasm has shown excellent competitive ability with various exotic grasses found in south Texas.

Figure 10.2. Shortspike Windmillgrass.

Sideoats Grama (Bouteloua curtipendula)

- 48 collections were evaluated.
- Evaluation locations were the PMC, TARS-B, RF, TARS-U, and Rancho Blanco (RB).
- Standards for comparison were the commercial varieties "Haskell," "Niner," "Vaughn," "Premier," and a selection from Mexico by Pogue Agri Partners.
- 8 accessions were chosen for initial seed increase and advanced evaluation.
- 5 accessions were selected for release as a blend of selected germplasms.
- Emergence and persistence in south Texas field plantings, and seed yields of the selected germplasms are superior to current commercial varieties of sideoats grama.
- A commercial release will be made in 2011–2012.
- Field plantings show rapid establishment characteristics and excellent competitive ability with buffelgrass and Kleberg bluestem.

Red Grama (Bouteloua trifida)

- 50 accessions were evaluated.
- Evaluation location was Bladerunner Farms (BF).
- Seed fill and germination averaged <2 percent.
- Plant survival more than 1 year was poor for most all accessions.
- Because of poor seed quality and stand life, work with the species was discontinued.

Texas Grama (Bouteloua rigidiseta)

- 25 accessions were evaluated.
- Initial evaluation location was BF, subsequent evaluations were performed at TARS-B, RF, STN Farm (STN), and RB.
- 6 accessions were selected for advanced evaluation based on seed germination experiments.
- 4 accessions were chosen for release based on advanced evaluation experiments.
- Work resulted in the release of Atascosa Germplasm Texas grama.
- Commercial seed is produced by Douglass W. King Seed Company.

- In highway plantings, Atascosa Germplasm readily establishes in very shallow, rocky microsites, caliche based soils, and along asphalt.
- Should be used as a minor component of most seed mixes.

Hairy Grama (Bouteloua hirsuta)

- 35 accessions were evaluated.
- Initial evaluation location was BF, subsequent evaluations were performed at TARS-B, RF, STN Farm (STN), and RB.
- 4 accessions were selected based on strong perennial habits, seed quality, and origin so as to provide a broadly adapted commercial source of this widespread species.
- Work resulted in release of Chaparral Germplasm hairy grama.
- Commercial seed is produced by Douglass W. King Seed Company.
- Release shows broad adaptability to different soil textures.
- Typical establishment requires more than 6 months after seeding because of seed dormancy.

Slender Grama (*Bouteloua repens*)

- 9 accessions were evaluated.
- Initial evaluation location was BF, subsequent evaluations were performed at TARS-B, RF, STN Farm (STN), and RB.
- 6 accessions were chosen for advanced evaluation because of superior seed quality and perennial habits.
- 4 accessions were chosen for release based on seed quality and plant characteristics.
- Work resulted in release of Dilley Germplasm slender grama.
- Commercial seed is produced by Douglass W. King Seed Company.
- Dilley Germplasm is the most consistent performer across all field plantings.
- Shows broad adaptation to south Texas soils and is the most competitive species evaluated with exotic grasses.
- Establishment is less than 60 days in most all plantings.

Figure 10.3. Slender Grama.

Arizona Cottontop (Digitaria californica)

- 49 accessions were evaluated.
- Evaluation locations were the PMC, RF, RB, TAR-U, and STN.
- Standards for comparison were the releases PMT-389 and "Loetta" Arizona cottontops.
- 12 accessions were chosen based on vegetative characteristics and seed germination.
- Work resulted in release of LaSalle Germplasm Arizona cottontop.
- Commercial seed is produced by Pogue Agri Partners.
- LaSalle Germplasm is a rapid establishing grass species for disturbed soils, and it is often one of the first native grasses to emerge from seed after planting.
- Best performance in field plantings has been documented on fine textured soils.

Plains Bristlegrass (*Setaria leucopila*) and Streambed Bristlegrass (*Setaria vulpiseta*)

- 150 collections were evaluated.
- Evaluation locations were PMC, TARS-B, TAR-U, and STN.
- 4 accessions were chosen for release based on seed quality.

- Each accession was released separately, under the names KIKA677, KIKA648, KIKA819, and KIKA820.
- Commercial seed is marketed as a blend of the releases under the name Catarina Blend Bristlegrass.
- Commercial seed is produced by Turner Seed Company, Douglass King Seed Company, and Pogue Agri Partners.
- Excellent field plant performance has been documented throughout south Texas.
- Establishment generally occurs 3 to 6 months after seeding.

Little Bluestem (Schizachyrium scoparium)

- 81 collections were evaluated.
- Evaluation locations were the PMC, BF, RF, TARS-B, TAR-U, RB, and STN.
- Standards for comparison were "OK Select," Turner Native, "Cimarron," and "Aldous."
- 4 accessions were chosen for advanced evaluation and seed increase.
- 2 of the 4 were selected for release as selected germplasms.
- 2 releases will be made (1 representative of eastern south Texas material, and 1 representative of western south Texas material) in 2011-2012.
- Commercial seed will be produced by Douglass King Seed Company and Pogue Agri Partners.
- Selections have shown greater long-term survival in south Texas than current commercial varieties of little bluestem.

Pink Pappusgrass (*Pappophorum bicolor*) and Whiplash Pappusgrass (*Pappophorum vaginatum*)

- 76 collections were evaluated.
- Evaluation locations were the PMC, RB, RF, TAR-U, and STN.
- 7 selections of pink pappusgrass and 3 selections of whiplash pappusgrass were made based on seed quality and uniformity.
- Work resulted in the release of Webb Germplasm whiplash pappusgrass and Maverick Germplasm pink pappusgrass.

- Commercial seed of Webb Germplasm is produced by Douglass King Seed Company, and commercial seed of Maverick Germplasm is produced by Pogue Agri Partners.
- Selections show very good competitive ability with common exotic grasses.
- Releases show good establishment and persistence in dry, shallow sites across a variety of planting locations in south Texas.
- Webb and Maverick Germplasm show good adaptation to saline and alkaline soils.

Figure 10.4. Pink Pappusgrass.

Common Curly Mesquite (*Hilaria belangeri*)

- 39 accessions were evaluated.
- Evaluation locations were BF and the PMC.
- Seed fill and germination averaged less than 1 percent.
- Transplant and vegetative methods of increase were unsuccessful.
- Work was discontinued with the species because of poor seed and vegetative production potential.

Halls Panicum (*Panicum hallii*)

- 46 accessions were evaluated.
- Evaluation location was the PMC and RF.
- 2 accessions were selected based on seed fill and seed retention.
- A release will be made in 2011.

Brownseed Paspalum (*Paspalum plicatulum*)

- 15 accessions were evaluated.
- Evaluation locations were the PMC, TARS-B, and RF.
- 4 accessions were chosen for release and increased at RF.
- Seed fill and production were inadequate for commercialization of these selections.
- A King Ranch/PMC selection of brownseed paspalum is currently being increased for possible release.

Silver Bluestem (Bothriochloa laguroides)

- 102 collections were evaluated.
- Evaluation location was the PMC.
- 5 selections were made based on seed quality.
- Selections are currently being increased at the PMC.
- A commercial release will be made 2012–2013.

Multiflowered False Rhodesgrass (*Trichloris pluriflora*)

- 59 accessions were evaluated.
- Evaluation locations were the PMC, RB, TAR-U, and RF.
- 5 accessions were selected based on seed quality characteristics.
- Selections are currently being increased at the PMC and STN.
- A commercial release will be made in 2011.
- Field planting performance has been excellent; however most establishment occurs 9 to 12 months after planting.

Figure 10.5. Multiflowered False Rhodesgrass.

Slim Tridens (*Tridens muticus* var. *muticus*) and Rough Tridens (*Tridens muticus* var. *elongatus*)

- 60 accessions were evaluated.
- Evaluation locations were TAR-U, RB, and STN.
- 2 accessions were selected (1 ea var. *elongatus*, and var. *muticus*) based on seed quality and accession uniformity.
- Accessions are currently being increased at STN.
- Release will be considered if seed production potential and stand life are found to be acceptable for commercialization.

Rio Grande Bristlegrass (Setaria reverchonii var. ramiseta) and Knotgrass (Setaria reverchonii var. firmula)

- 35 accessions were evaluated.
- Seed quality and germination were too poor to produce transplants for evaluation.
- Work with these species was discontinued because of poor seed quality.

Purple Threeawn (*Aristida purpurea*)

- 27 collections were obtained.
- Seed processing studies were conducted to determine if large scale mechanical harvest and processing techniques could be developed.
- Current technology and methods prevent effective commercialization of the species.

Wrights Threeawn (Aristida wrightii)

- 24 collections were obtained.
- Seed processing studies were conducted to determine if large scale mechanical harvest and processing techniques could be developed.
- Current technology and methods prevent effective commercialization of the species.

Plains Lovegrass (Eragrostis intermedia)

- 8 collections were evaluated.
- Evaluation locations were the PMC and STN.
- One accession showed potential for commercialization based on vegetative characteristics and seed quality.
- Increase of the selected accession is currently being conducted at the PMC.
- Additional collections are being obtained for comparison to determine if the selected accession warrants release.

Green Sprangletop (*Leptochloa dubia*)

- 11 collections were evaluated.
- Evaluation location was the PMC.
- Standard for comparison was “Van Horn” green sprangletop.
- Accessions evaluated showed no superior performance characters to Van Horn.
- Evaluation of new collections was discontinued.
- “Van Horn” green sprangletop is recommended for use in south Texas.

Texas Panicum (*Urochloa texana*)

- 1 collection was evaluated.
- Evaluation was discontinued because numerous common varieties of the species are available commercially.
- Source-identified seed of Texas Panicum can be obtained commercially and is recommended for use.
- Seed source used should originate from the ecoregion where it will be planted whenever possible for good performance.
- Evaluation of Texas panicum seed originating from areas beyond south Texas shows consistent planting failures, whereas ecotypic seed results in acceptable planting results.

Engelmann Daisy (Engelmannia pinnatifida)

- 11 collections were evaluated.
- Evaluation location was the PMC.
- Standard for comparison is "Eldorado" Engelmann daisy.
- Populations under evaluation show potential for improvement over "Eldorado."
- Additional collections are being sought for continued study of the species.

Awnless Bush Sunflower (*Simsia calva*)

- 28 accessions were evaluated.
- Evaluation locations were TAR-U, PMC, STN, and RF.
- Standards for comparison were "Plateau" and a commercial source from Native American Seed Company.
- 5 accessions were selected based on flower height and vegetative characters facilitating harvest.
- Selected accessions are currently being increased at STN.
- A release of the species will likely be made in 2012–2013.

Rio Grande Clammyweed (Polanisa dodecandra ssp. riograndensis)

- 5 accessions were evaluated.
- Evaluation locations were the PMC, RF, RB, and STN.

- 2 accessions were chosen for release as Zapata Germplasm Rio Grande clammyweed.
- Commercial seed is produced by Rio Farms, Inc., and Douglass King Seed Company.
- Zapata Germplasm shows excellent performance when used as a warm-season, annual cover crop on disturbed sites.
- Zapata Germplasm readily establishes on a variety of planting sites and competes well with annual and perennial weeds common to south Texas.

Redseed Plantain (*Plantago rhodosperma*) and Hookers Plantain (*Plantago hookeriana*)

- 25 accessions were evaluated.
- Evaluation locations were the TARS-B, STN, and RF.
- 2 selections (1 of each spp.) were made based on seed yields.
- Work resulted in the release of STN-496 Germplasm redseed plantain and STN-562 Germplasm Hookers plantain.
- Commercial seed is marketed at a blend of the 2 releases under the name Divot Tallow Weed Blend.
- Commercial seed is produced by Pogue Agri Partners.
- Divot Tallow Weed Blend shows excellent performance as a cool-season, annual cover crop on disturbed sites.
- Divot Tallow Weed blend readily establishes on a variety of soil types.

Orange Zexmenia (*Wedelia hispida*)

- 76 accessions were evaluated.
- 7 accessions were selected and increased based on seed quality, harvest ability, tolerance to disease, and origin.
- Work resulted in release of Goliad Germplasm orange zexmenia.
- Seed for commercial production will be provided to a grower once adequate quantities are produced.

Figure 10.6. Orange Zexmenia.

Other Species Considered and Evaluated

- **Big bluestem (*Andropogon gerardii*)** - 2 selections have been made and are being tested and increased for possible release.
- **Big sacaton (*Sporobolus wrightii*)** - the PMC has released Falfurrias Germplasm big sacaton. It is an excellent species for riparian areas, and saline soils in south Texas. This species can be used as a native substitute to pampasgrass in ornamental plantings along highway rights of way.
- **Bundleflower (*Desmanthus virgatus*)** - 3 selections have been made and are being tested in comparison to other commercial cultivars ("Beewild," "Sabine," and "Hondo").
- **Canada wildrye (*Elymus canadensis*)** - Lavaca Germplasm Canada wildrye has been released by the PMC. It is an excellent cool-season grass and may be used as a temporary native cover crop. Commercial seed is produced by Turner Seed Company.
- **Crinkleawn (*Trachypogon secundus*)** - Evaluations showed limited ability to harvest and process seed; limited natural range of plant results in limited commercial interest.
- **Dalea spp**. **(*Dalea emarginata, Dalea nana, Dalea aurea,* and *Dalea pogonothera*)** - evaluations show poor seed production potential of most species evaluated, and very specific adaptation to soil types.

- **Deer pea vetch (*Vicia ludoviciana*)** - germplasm developed by TARS-B shows high potential for release and beneficial use as a cool-season annual cover crop. Release is being considered for 2012, and commercial seed is being produced by Pogue Agri Partners.

Figure 10.7. Deer Pea Vetch.

- **Partridge pea (*Chamaecrista fasciculata*)** - collections evaluated showed wide variability based on origin. Seed production potential was low for most south Texas populations. "Comanche" partridge pea showed similar performance as ecotypic sources in our evaluations. However, "Comanche" is ectopically dissimilar to south Texas populations, and field performance in most south Texas plantings is poor.
- **Prairie acacia (*Acacia angustissima*)** - evaluations showed excellent potential of this herbaceous legume. Three selections have been made and a release will be made in 2011.
- **Texasgrass (*Vaseyochloa multinervosa*)** - evaluations indicated high seed yields and seed quality of all accessions. However, similar to crinkleawn, this species has a limited natural range and therefore little demand.

- **False rhodesgrass (*Trichloris crinita*) -** the PMC has release Kinney Germplasm false rhodesgrass. This release is an excellent species for fine textured soils west of IH 37 in south Texas. Commercial seed is produced by Douglass King Seed Company.
- **Wooly croton (*Croton capitatus*) -** south Texas populations evaluated had inferior performance to commercial source available from Turner Seed Company.
- **Yellow Indiangrass (*Sorghastrum nutans*) -** one selection was made that showed superior performance in vegetative characters in comparison to other south Texas populations and the cultivars "Cheyenne" and "Lometa." Seed quality of the south Texas selection has proven erratic, and release and commercial production are unlikely.

Figure 10.8. False Rhodesgrass and Whiplash Pappusgrass.

CHAPTER 11: SEED RELEASES AND COMMERCIALIZATION STATUS

Figure 11.1. Commercial Seed Production Field of Dilley Germplasm Slender Grama.

Through this project, 17 native seed releases were made. Three seed releases previously developed by the USDA NRCS E. "Kika" de la Garza Plant Materials Center were assisted in being made commercially available. Now, 20 varieties of native seed are being grown commercially, already resulting in the availability of native seed for use by TxDOT and other restoration seed consumers. While commercialization of these releases has been a long-term process, we believe that once stable production is established, resulting in consistent demand from agencies like TxDOT, most all of these releases will be commercial successes.

RELEASE PROCESS

Following final selection of best-performing accessions in the evaluation and seed increase stages, a decision to release a species was made by the research team. Release considerations depended on divergent factors for each species, but some commonalities existed that influenced the decision to release a plant species. These factors included:

- **Broad potential consumer demand for seed of the plant species.** Demand for uses such as highway rights-of-way revegetation use, coupled with interest in the plant from rangeland management, wildlife habitat restoration, and ranching interests,

coupled with interest in use by the USDA Farm Service Agency Conservation Reserve Program or NRCS Environmental Quality Incentive Program generally indicated a species with adequate demand potential to justify release.

Figure 11.2. Commercial Seed Production Field of Mariah Germplasm Hooded Windmillgrass.

- **Economically feasible seed production from commercial producer and end-user standpoints.** According to most commercial producers worked with in the project, most native grasses must have a ratio of roughly 25 lb PLS yield per acre: 2 lb per acre PLS seeding rate. Grasses with ratios numerically closer than this result in too high of cost seed for most consumers. For example, slender grama (Dilley Germplasm release) is recommended to be planted at 8 lb PLS per acre and commercial seed fields yield about 150 lb PLS per acre. This yield results in slender grama seed priced at around $20 per PLS lb, or $160 per acre based on the pure stand seeding rate. For native seeding, this cost falls within the amount economically feasible for a large sector of consumers. Contrast this with crinkleawn, a species with low yields of just 25 lb PLS per acre and a seeding rate near 10 lb PLS per acre. If this species were produced commercially, seed would likely cost $120 per PLS lb,

and at the recommended planting rate for the species, it would cost $1,200 per acre for seed. Obviously, this cost is infeasible for the majority of consumers.

Figure 11.3. Commercial Seed Production Field of Zapata Germplasm Rio Grande Clammyweed.

- **Most forbs have high production and seed cost because of low seed yields.** But, since forbs are typically only minor parts of most native seed mixes, release of these species were still justified by widespread demand whenever a forb species was found that met other criteria for release.
- **Large geographic adaptation.** Species that grow only in specific soil series, or that have geographically small areas of adaptation are not likely to have large enough markets to justify commercial production. An example is Texasgrass, a narrowly distributed, endemic grass to the South Texas Sand Sheet. While an important native species, and one with excellent characteristics for commercial seed production, the potential market is too small to stimulate interest by commercial producers. Texasgrass would likely have a single demand sector (highway right of way plantings), since most areas where the grass is adapted are relatively high-condition native rangeland that are unlikely to require reseeding. Compare Texasgrass to hooded windmillgrass, which grows well in most every soil type and county in south

Texas and adjacent regions. Uses include most all native seed applications, from highway right of way plantings, to range and wildlife plantings, to erosion control plantings. As a result, commercial growers would be more likely to desire to produce hooded windmillgrass than Texasgrass.

Once a decision to release a species was made based on these factors and evaluations of performance, a formal release packet was drafted. The release process requires formal summaries of all data collected, as well as supporting information about the species such as plans for commercialization, and environmental analysis. Release packet deliverables (release document, brochures, and published notice of release articles) are included in Appendixes A, B, and C of this document. Release of a species required the following information:

1. Release proposal including:
    a. Proposed name and variety designation.
    b. Botanical name, family, genus, and species.
    c. Origin and breeding/selection history of the variety.
    d. Objective description of the variety.
    e. Evidence for release (data summaries of initial evaluation, advanced evaluation, seed increase, and seeding trials).
    f. Seed production, harvest, and cleaning information.
    g. Area of known adaptation.
    h. Procedure for maintaining stock classes of seed.
    i. Description of how the variety is to be constituted.
    j. Additional restrictions.
    k. Ecological considerations and evaluation.
    l. Potential conservation uses.
    m. Availability of plant materials.
    n. References.
    o. Tables and figures supporting release.
    p. Map of collection, evaluation, and experimental planting sites.
    q. Photograph of representative specimens of the variety.
    r. Signatures for release.

i. Director of the Caesar Kleberg Wildlife Research Institute at Texas A&M University-Kingsville.
ii. Dean of the Dick and Mary Lewis Kleberg College of Agriculture, Natural Resources, and Human Sciences at Texas A&M University-Kingsville.
iii. Director of Texas AgriLife Research.
iv. State Conservationist of USDA NRCS Texas.
v. Director of the Ecological Sciences Division of the United States Department of Agriculture.

2. Letter stating confirmation of botanical identification of submitted specimens (performed by Dr. Stephen Hatch of Texas A&M University S.M. Tracy Herbarium).
3. Submission of plant specimens to the National Plant Materials Center Herbarium and the National Arboretum.

Figure 11.4. Commercial Seed Production Field of Maverick Germplasm Pink Pappusgrass.

4. Submission of seed of the variety to the National Plant Germplasm System repository.

5. Proof of completion of the USDA NRCS Form 540.90-Worksheet for Documenting an Environmental Evaluation of NRCS Plant Releases.
6. Completion of USDA NRCS Conservation Plant Release Review Worksheet.
7. Memorandum or letters showing proof of interest in production of the variety by commercial seed producers.
8. Memorandum presenting current and anticipated breeder and foundation seed stock, and current production capacity of the developer.
9. Letter from USDA NRCS specifying clearance of the name selected for the release following review according to the International Code for Nomenclature for Cultivated Plants, Association of Official Seed Certifying Agencies, and National Plant Materials Program guidelines.
10. Preparation and publication of a release brochure for use by commercial producers and consumers.
11. Preparation and publication of a notice of release journal article in Native Plants Journal.
12. Preparation and publication of a news release announcing the release.
13. Plant variety/germplasm release disclosure form for Texas A&M System Office of Technology and Commercialization.
14. Texas AgriLife Research Plant Review committee cover sheet including:
    a. Crop type.
    b. Proposed name and identification.
    c. Designation or name in development stages.
    d. Primary features or advantages of the release.
    e. Plant Variety Protection intent.
    f. Seed amount and date of availability.
    g. Proposed distribution method.
    h. Royalty collection intent.
    i. Suggested fees.
    j. Supportive documents (release proposal).
    k. Submission signatures (TAR breeder and Station Directors of collaborating TAR/TAMU scientists).

Figure 11.5. Commercial Seed Production Field of Catarina Blend Bristlegrass.

Once each release packet is compiled, all documents are reviewed by each collaborating entity and the supervisors of the personnel involved in the development of the release. Release packets are also reviewed by senior faculty of TAMUK, the Texas A&M Department of Crop and Soil Sciences/Texas Foundation Seed Service Plant Review Committee, and the USDA NRCS Texas Plant Materials Specialist, Southern Region Plant Materials Specialists, and the Texas State Resource Conservationist.

Typically, 1–2 years of review and revisions were required between final decision to release and final approval for release was granted by all collaborating entities. A table listing all release made under these procedures is presented in Appendix D.

Figure 11.6. Commercial Seed Production Field of LaSalle Germplasm Arizona Cottontop.

COMMERCIALIZATION

Following official release, efforts were begun to ensure successful commercialization of each release and eventual availability of seed to consumers. This began by informally polling potential seed producers to gauge interest in producing the release. In early stages of the project, commercial growers were difficult to convince to grow releases. However, as demand for such seed sources increased, seed dealers began to compete heavily for production rights for each release. To equitably determine the best grower, inspections of potential growing sites were made and evaluated against the knowledge of the production requirements and climatic and edaphic adaptation of the release. Furthermore, grower selections were refined with assistance from the Texas Foundation Seed Service based on past production histories available for review. Additionally, producers willing to begin commercial production by vegetatively establishing seed fields using transplants instead of by direct seeding were given preference for seed distribution. We typically choose a single grower to initially produce each new release. If necessary to ensure rapid commercialization, term-limited, exclusive, or non-exclusive production rights were granted to the grower with the help of the Texas A&M System Office of Technology and Commercialization. All releases are eligible for sale by multiple growers, regardless of the producer, licenses, or other restrictions.

Once a grower was selected, available Breeder-level seed of the release was distributed to them. Throughout the establishment phases, assistance was provided in planting and managing the new crop. Estimates of the amount of production needed to meet market projections were developed by project personnel and the grower, and long-term production plans were initiated to achieve the milestones and ensure commercial availability of seed. For most releases, 1–2 years were needed for establishment of initial acreages, and by years 2–5 significant commercial production amounts were produced and available for sale to consumers. Final target production amounts to meet the expected demand of most releases were met within 2–5 years of the release of most varieties. Current commercial production status of each release is given in Appendix E.

CHAPTER 12: RECOMMENDATIONS AND FUTURE WORK

Figure 12.1. Native Grassland Restored Using Project Seed Releases.

Developing commercially viable native seed products is a time-intensive, laborious, and expensive process. But, it is necessary if performance-based and quality controlled native seed sources are desired for restoration of disturbed soils along highway right of ways. Restoration of Texas' highway right of ways is an extremely difficult task, but one worthwhile of TxDOT's investment in this project and future efforts like it in other parts of the state. TxDOT's role in the native seed market is enormous, given that highway rights of way are one of the largest single land uses in the state, and the agency is one of the largest single consumers of native seed in Texas.

Such seed sources as those developed in this project have high potential for long-term benefit and near-indefinite availability for use so long as breeder seed is produced and maintained by the developers. For example, Haskell sideoats grama, a very successful native seed release of the USDA NRCS James E. "Bud" Smith Plant Materials Center was formally released in 1983. This native seed release has been available for use by those desiring native plant restoration seeding almost 30 years. The impact of a native seed releases on conservation and restoration can be profound. Haskell has been used on countless thousands or hundreds of thousands of acres of highway rights of way and Conservation Reserve Program plantings. We

look forward to and hope releases made by this project will have similar beneficial impacts over the coming century.

Even though 20 seed releases have now been developed for south Texas, more work is needed to ensure successful commercial availability and use of native plants on Texas' roadsides. Additional areas of Texas have similar native seed sources needs as south Texas did when this project began. The collection, selection, increase, and release of native seeds for these areas is greatly needed. We recommend the successful methods developed in this project be similarly followed elsewhere in the future. Areas of particular need are west Texas, areas of central Texas, the upper Gulf Coast region of Texas, and most all of East Texas.

The range and limits of adaptation of the native seed sources developed in this project, as well as other previous native seed releases made by other agencies in Texas need be more well defined. Currently, the areas of adaptation of most native seed releases are simply hypothesized; they have not been thoroughly tested, nor have the results of tests been made available to TxDOT and other seeding practitioners. Such publications would be of great help to TxDOT and other natural resources managers. Perhaps no other attribute of native seed would be as useful at influencing consumer demand, and in turn commercial seed production, as succinct limits and areas of adaptation for native seed sources would.

Furthermore, commercial seed stocks of most all native seed sources are too low, or availability varies too greatly to allow widespread use and specification of such seed by agencies, landowners, and conservation programs. Without consistent commercial production and availability in needed amounts, TxDOT's inclusion of many native seed sources in their Vegetation Specifications will be difficult. To overcome this problem, greater efforts to provide large amounts of Breeder and Foundation Seed Stocks must be undertaken. Such seed is necessary to maintain, or increase commercial seed supplies over time. In our experience, the presence or existence of adequately-funded, regional native seed initiatives are necessary to solve this problem. Such native seed initiatives, of which the South Texas Natives Project is an example, have the flexibility, expertise, and geographic location necessary to rapidly produce and distribute Breeder and Foundation level seed to commercial growers when needed to maintain or increase commercial acreage to meet demand for seed supplies.

Seed increase and Breeder and Foundation seed maintenance operations will require strong collaboration and open dialogue between seed consumers and seed producers. Regional

native seed initiatives, by way of receiving guidance from all parties through Technical Advisory Committees, and maintaining open lines of collaboration, can receive and communicate this information between parties, as well as take action affirmatively in support of the needs or problems identified. Only by coalescing inputs from the various seed demand sectors (e.g., TxDOT, NRCS, oil and gas industry, private landowners), can a true picture of the native seed market be gained. There is great value in having trained staff employed by regional native seed initiatives who can balance and tally each seed use sector's needs, devise production plans to produce the seed necessary, and finally communicate with and assist commercial seed industry on establishing, managing, and marketing native seed crops. Currently, no other agency, academic research group, private entity, or unit of government provides such a service as it pertains to native seed in Texas. While South Texas Natives is a strong regional seed initiative in south Texas, need exists for such units in most every other part of the state.

The end goal of the South Texas Native Plant Restoration Project was the development and implementation of native seed mixes by the Texas Department of Transportation in south Texas. Through work with the Vegetation Management Section, special seeding provisions utilizing native seed developed in this project have been developed for the Pharr and Corpus Christi TxDOT Districts (Tables 12.1 and 12.2). Approval of the specifications, and implementation of these native grass seed mixes, will represent partial achievement of the overall goal of this project. In years to come, as commercial seed quantities reach adequate levels, we hope native-only seed mixes will be able to be specified for all south Texas TxDOT districts.

Table 12.1. Proposed Special Provision Native Seed Mix Specification for Clay Soils in the Pharr and Corpus Christi TxDOT Districts.

Clay Soils		
Species	**Variety**	**Lbs PLS per acre**
Green sprangletop	Van Horn	**0.1**
Sideoats grama	Haskell	**0.35**
Sand dropseed	NS	**0.1**
Slender grama	Dilley Germplasm	**2**
Hairy grama	Chaparral Germplasm	**0.1**
Texas grama	Atascosa Germplasm	**0.75**
Hooded windmillgrass	Mariah Germplasm	**0.1**
Shortspike windmillgrass	Welder Germplasm	**0.05**
Bristlegrass	Catarina Blend	**0.15**
Arizona cottontop	LaSalle Germplasm	**0.15**
Pink pappusgrass	Maverick Germplasm	**0.2**
Whiplash pappusgrass	Webb Germplasm	**0.2**
Canada wildrye	Lavaca Germplasm	**0.1**

Finally, as better adaptation information is provided, and commercial seed stocks of native plants reach necessary levels, TxDOT should consider substantially rewriting their seeding specifications to include only native vegetation. Such action would be well-received throughout the state, set precedence, and perhaps most importantly, dramatically influence seed markets away from the production, sale, or use of exotic, often invasive, restoration and reclamation seeds in the State of Texas. While performance of exotic vegetation often adequately meets engineering standards, the current use of exotic species as bermudagrass, buffelgrass, or Lehman lovegrass directly contradicts Texas' shift away from traditional livestock-production systems, to rural land use systems focused on natural resources management and native landscapes. The opportunity exists for TxDOT to become *the leader* in the use of native seeds for restoration in Texas. Our hope is that this project has helped ensure future generations' drives down south Texas highways will be framed by native plants. The same can be true for the entire state with TxDOT's continued leadership and support.

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