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Revegetation Practices on the Santa Rita Experimental Range

Abstract: This paper discusses the revegetation activites on the Santa Rita Experimental Range since 1903. Revegetation research includes experiments to evaluate adaptation, seedbed preparation, and sowing methods. We also discuss criteria used to determine if a site has the potential for a successful revegetation. Successful revegetation was initially based on plant emergence and establishment but not persistence. Plants in successful plantings typically died or the initial stand declined substantially within about 10 years. Revegetation trials typically used native and introduced species. However, introduced species such as Lehmann lovegrass (*Eragrostis lehmanniana* Nees) more successfully established and spread. Lehmann lovegrass is invading and reducing the biodiversity of the semidesert grasslands. Scientists and others are now emphasizing revegetation with native plants. The Santa Rita Experimental Range will continue to serve as an outdoor laboratory in the search for revegetation methods, combined with the use of native species, to improve the biodiversity as well as watershed stability of the semidesert grasslands.

Keywords: Lehmann lovegrass, native plants, reseeding, seedbed, and transplanting

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Introduction

From the late 1800s through the early 1900s woody plants increased and grasses decreased on rangelands throughout the Southwestern United States and Northern Mexico (Roundy 1995). Declining forage conditions and increased erosion led scientists and land users to attempt to develop management practices to improve the vegetation on these rangelands. Experimental ranges were created to serve as centers for the study of rangelands and development of information and practices that would protect, restore, and provide for the proper management of these environments. The Santa Rita Experimental Range (SRER) was established in 1903 to serve as an experimental range for the arid Southwest (Medina 1996). Early revegetation studies at the SRER and elsewhere in southern Arizona were conducted by D. A. Griffiths and J. J. Thornber. Griffiths' work began in southern Arizona in 1904 and utilized both native and introduced perennial forage species. He incorporated the use of furrows to concentrate and store moisture in an effort to improve plant establishment. Poor results from these plantings directed Griffiths to conclude that annual plants were better suited for revegetation of desert rangelands (Glendening and Parker 1948). In 1910 Thornber, based on his work in southern Arizona, reported that introduced forage plants were not well adapted to the desert rangelands, and that native plants that are ecologically adapted to the desert and to soils that are subject to flooding gave the best results in his trials (Glendening and Parker 1948). E. O. Wooton's revegetation trials in 1916 at the SRER supported Griffiths' and Thornber's earlier findings that, with the exception of annual filaree (*Erodium cicutarium* (L.) L'He'r. ex Ait.), revegetation with introduced grasses was not likely to be successful. While revegetation studies began soon after the SRER was established (Martin 1966), a formal range revegetation program did not

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begin until 1935. Glendening and Parker (1948) stated that the most successful species to use in rangeland revegetation within the semidesert grassland, based on revegetation experiments at the SRER, were Boer lovegrass (*Eragrostis curvula* (Schrad.) Nees), Lehmann lovegrass (*E. lehmanniana* Nees), and Wilman lovegrass (*E. superba* Peyr.). However, most revegetation trials resulted in failure. Most often this was attributed to a lack of adequate moisture for plant establishment. This led to the search to find drought-tolerant plant species for use in revegetation. Scientists and others experimented with innovative methods in seedbed preparation and evaluating introduced species in search of methods and species that would successfully revegetate severely eroding rangelands (Roundy 1995). In southern Arizona, these “miracle plants” appeared to be primarily the exotic lovegrasses from Southern Africa. Several lovegrass species were tested for revegetation use on the SRER. The most successful was Lehmann lovegrass. The revegetation program conducted by the Rocky Mountain Forest and Range Experiment Station ended on the SRER in the mid-1950s (Medina 1996).

Since 1939, the U.S. Department of Agriculture, Natural Resources Conservation Service, Tucson Plant Materials Center (PMC) has conducted plantings on the SRER. The SRER has provided the PMC with long-term evaluation sites for comparison of the potential of native and introduced species for revegetation on Southwestern rangelands. The most recent experimental planting was established in 1968. Eighteen different plantings (12 warm season and 6 cool season) were conducted at this site from 1968 through 1988. This site is located in pasture 5N south of Desert Tank on Road 401 (SW ¼ of the SW ¼ of Section 3, Township 18 south and Range 14 east). The objective of these plantings was to determine the production and erosion control potential of native and introduced species selected from the PMC testing program for the arid Southwest (USDA 1988).

Revegetation Principles

Researchers have attempted to describe factors to consider when determining if revegetation is feasible. The number of factors varies depending on the author but generally includes (1) site selection, (2) seedbed preparation, (3) species selection, and (4) seeding method (Anderson and others 1957; Jordan 1981; Martin 1966; Roundy and Biedenbender 1995). The following discussion is a review of the many efforts conducted at the SRER to enhance our knowledge of these factors.

Site Selection

Based on revegetation trials on the SRER, Anderson and others (1957) summarized the many factors to consider when determining if a revegetation effort is feasible. Site selection should be based on local climate and soil types. Sites should have medium textured soils with moderate infiltration rates, good waterholding capacities, be at least 2 ft deep, and receive 11 inches of average annual precipitation. Sites that receive less precipitation may be expected to have successful seedings only in above-average rainfall years. In drought years, even seedings on favorable sites may result in failure. Existing vegetation can indicate the area’s forage production potential. Areas with dense cover may indicate deep soils with good waterholding capacity and the potential to produce forage. Anderson and others (1957) suggested that the existing plant community may be used to determine if revegetation efforts will be successful. Stands of mesquite (*Prosopis velutina* Woot.) and burroweed (*Isocoma tenuisecta* Greene) are good indicators of sites suitable for revegetation and supporting grass. Species like saguaro (*Carnegiea gigantea* (Engelm.) Britton & Rose), paloverde (*Parkinsonia* spp. L.), triangle leaf bursage (*Ambrosia deltoidea* (Torr.) Payne), and ironwood (*Olneya tesota* Gray) indicate sites that are arid and droughty and unsuited to revegetation. Dense stands of woody vegetation must be controlled before attempting to reseed. Anderson and others’ (1957) research on the SRER found that if mesquite density exceeded 15 to 25 trees per acre they had to be controlled prior to revegetation. Also, if burroweed was a principal component of the plant community it would have to be removed prior to revegetation. Revegetation is seldom justified on those areas where desirable grasses remain and stand recovery can be obtained following proper grazing management practices. Reynolds (1951), based on his work at the SRER, suggested that with an appropriate rest period sandy loam soils in semidesert rangeland that have an existing 10- to 20-percent stand of Rothrock and black grama should not be recommended for revegetation with Lehmann lovegrass. Reynolds suggested that a rest period of 8 to 10 years is needed on these sites for native grass stands to recover to similar forage production as similar-aged stands of seeded Lehmann lovegrass. Cox and Jordan (1983), from their rangeland revegetation work in southeastern Arizona, suggested that revegetation should be discontinued in the Chihuahuan Desert if it is based on an expected gain in livestock numbers. They stated that a successful seeding can be expected in 1 of 10 years in the Chihuahuan Desert of southeastern Arizona, and that forage production from a successful seeding can be expected to decline over a 10-year period. Sites heavily infested with cholla and pricklypear cacti (*Opuntia* spp. P.Mill.) are seldom suitable for revegetation because the physical manipulation required to prepare the seedbed would aid in dissemination of cactus propagules and increase their density. Martin (1966) stated that competitors, especially woody plants, should be removed or controlled prior to revegetation. Livingston and others (1997) found that Bush muhly (*Muhlenbergia porteri* Scribn. ex Beal) had greater density and cover under overstory woody species compared to open areas on their research plots at the SRER, suggesting that shade-tolerant species may emerge and persist if seeded under overstory plants.

Selection of revegetation sites should incorporate proper management of the site after revegetation. Revegetation sites should be rested from grazing for at least 1 to 2 growing seasons to allow young plants to become established. The site should be managed so that livestock or other grazers are not allowed to concentrate and overutilize the reseeded area. When planning a revegetation project, care should be given to its size so the reseeded area can be incorporated into the overall management plan and be properly managed. Also, indigenous fauna (rodents and rabbits) can have a significant impact on the success of a revegetation project (Anderson and others 1957), especially small revegetation projects.

Jordan (1981) summarized that site selection should be based on climate, soils, and terrain. The site must have the potential for successful establishment and ability to support the proposed revegetation. The terrain and soil types must be suitable to support the desired vegetation change. Shallow, coarse, rocky, saline, and or alkaline soils should be avoided, as should terrain with slopes above 30 percent.

In southern Arizona, Jordan (1981) proposed that seeding sites should ideally receive an average of 5.5 inches of precipitation in July, August, and September and at least 11 inches of average annual precipitation to be considered for potential revegetation. In his summary of revegetation activities on the SRER, Martin (1966) indicated that seeding should take place in May or June prior to the start of the summer rainy season. Roundy and others (1993) conducted laboratory germination experiments with regard to seeding depth and water availability for three grasses used in semidesert revegetation. Their results indicated that these grasses required frequent rainfall events for establishment. Lack of frequent rainfall events may be one reason many of the revegetation activities in the Southwest have poor results. Research by Abbott and Roundy (1995) on the SRER suggested that native grass seedings should take place the third week of July to increase the chance of successful establishment. They found that native grasses germinated faster than Lehmann lovegrass, especially when sown as naked caryopsis. By waiting to seed until the third week of July there is a greater opportunity of receiving rainfall events that are 5 days apart or less.

Seedbed Preparation

Wooton's revegetation recommendations based on research conducted between 1913 and 1916 on the SRER were to broadcast native seed onto bare ground without preparing the seedbed (Glendening and Parker 1948). Wilson's work, conducted from 1927 to 1931 in southern and central New Mexico, determined that the best revegetation results were obtained by seeding just prior to summer rains with little or no seedbed treatment except when a mechanical treatment was needed to control competition (Glendening and Parker 1948). Bridges work (Glendening and Parker 1948) from 1938 to 1941 in southern New Mexico indicated that seedbed preparation was necessary to ensure a successful revegetation. The equipment he used was a two-row lister followed by a 6-ft drill. Glendening and Parker (1948) stated that the eccentric disk-cultipacker seeder, developed by the Soil Conservation Service, was the best piece of equipment for preparing the seedbed and seeding. On sandy soils, successful revegetation has been achieved by broadcasting directly onto the soil surface (Glendening and Parker 1948).

Range trials in 1951 used a Krause cutaway disc to prepare the seedbed, tilling to a depth of 2 to 4 inches. This seedbed preparation implement was commonly used in the 1950s prior to broadcast seeding and cultipacking (Reynolds 1951). Martin (1966) suggested that planting methods should ensure proper seed placement in the soil surface, ¼ inch for fine-seeded species and up to 1 inch deep for large-seeded species, and promote moisture penetration into the soil. Successful seedbed preparation methods include pitting, contour furrowing, ripping, and imprinting (Reynolds and Martin 1968). Slayback and Cable (1970) conducted a 4-year trial to evaluate the effectiveness of "intermediate pits" and conventional pits on three different soil types (sandy loam, loam, and clay loam) on the SRER at the old PMC site that was north of the intersection between roads 505 and 401. The conventional pits were constructed using a standard pitting disc, creating a pit that was 18 to 24 inches long, 12 inches wide, and 6 inches deep. Intermediate pits were constructed with the basin-forming machine developed by Frost and Hamilton (1964) (fig. 1), which created broad, shallow pits 5 ft wide, 5 to 6 ft long, and 6 inches deep. The intermediate pit was developed to create pits that had a longer effective life. Conventional pits were effective for initial plant establishment, but they filled with soil after intense rainfall events and lost their ability to concentrate water within the first year or two. The average forage production over a 4-year period was 2½ times greater in the intermediate pit (basins) as in the standard pit (Martin and Cable 1975). Slayback and Renney (1972) compared bulldozer pits, reportedly similar to the pits made by the Frost basin-forming machine, to conventional pits or interrupted contour furrows, and their brand of "intermediate pits" (fig. 2) at the current PMC site located approximately 1 mile south of Desert Tank on road 401. Slayback and Renney's intermediate pits differed from Frost's intermediate pits primarily in the type of equipment used to construct them. Slayback and Renney used a tractor with a three-point hitch-mounted blade to form pits that were approximately the same size as the pits formed by Frost's basin forming machine. A rangeland drill was used to sow the seeds into the pits compared to Frost's machine that formed pits and planted the seed in a single operation. Herbage production and stand counts were taken over the 4-year planting effort. Their results indicate that the intermediate pit was more effective with

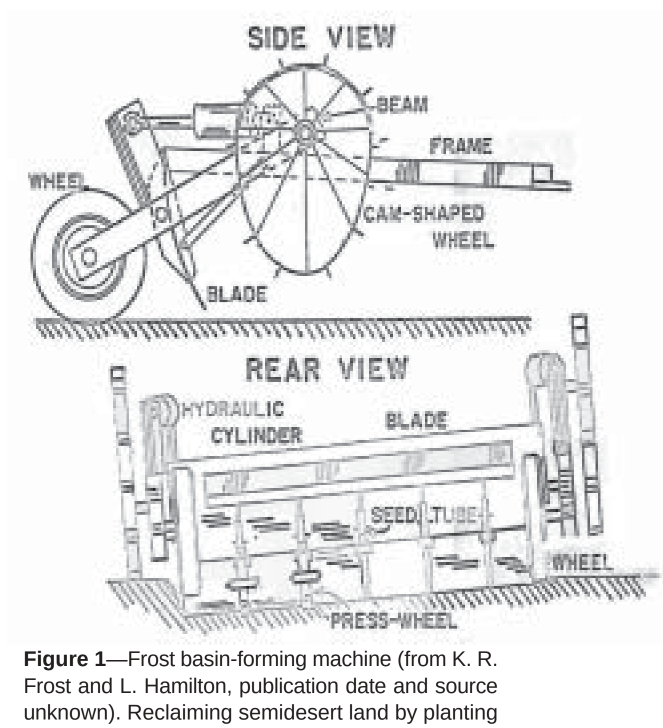

Figure 1—Frost basin-forming machine (from K. R. Frost and L. Hamilton, publication date and source unknown). Reclaiming semidesert land by planting perennials in basins on uncultivated soils (available in Paper Archives at U.S. Department of Agriculture, Natural Resources Conservation Service, Tucson Plant Materials Center).

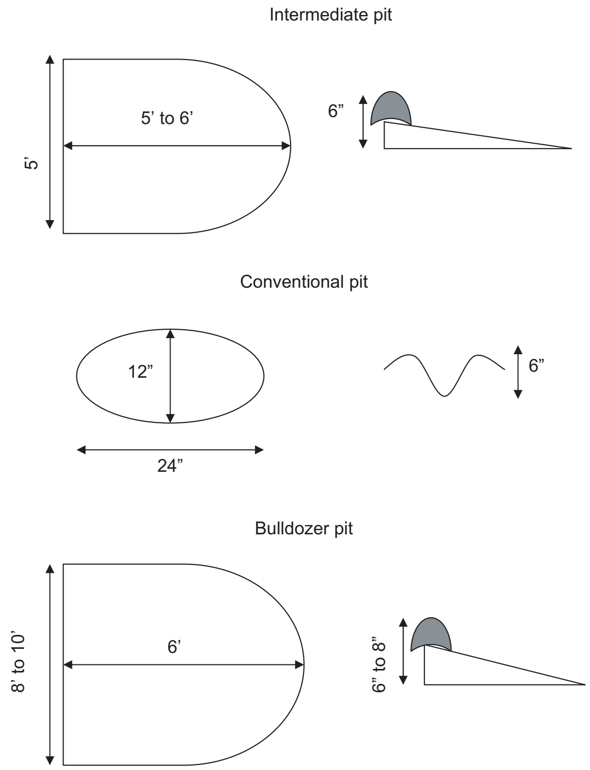

Figure 2—Pit types used on the Santa Rita Experimental Range by NRCS at the Desert Tank planting site (adapted from Slayback and Cable 1970).

regard to stand establishment and forage production than the conventional pit and the bulldozer pit treatments.

At the current SRER PMC site, one or more seedbed treatments were incorporated in all experimental plantings from 1968 to 1988. Treatments included intermediate pits, disking, or contour furrowing after ripping. Intermediate pits were created as described by Slayback and Renney (1972) along a 200-ft row perpendicular to the slope. Intermediate pits were used in 11 of the 18 plantings at the PMC site, while only three plantings used the disked treatments and only one used the furrowed following ripping treatment. Only two planting dates (1983 and 1984) resulted in good stand establishment and persistence of seeded species using the intermediate pits. The disked seedbed treatment had similar results with regard to percent stand and persistence in most plantings, but in the 1982 planting the stand persistence was much lower than the intermediate pits.

Cattle trampling has been another method recommended for preparing a seedbed that would encourage seedling establishment (Winkel and Roundy 1991). In the Altar Valley south of Three Points, Winkel and Roundy (1991) compared seedling emergence using cattle trampling, land imprinting, and ripping as seedbed preparation treatments. They found in years where summer precipitation provided available soil surface water for at least 3 weeks, land imprinting and heavy cattle trampling increased plant emergence for Blue panic (*Panicum antidotale* Retz.) and "Cochise" atherstone lovegrass (*Eragrostis trichophora* Coss. and Dur.). In years where summer precipitation provided available soil water for 6 to 9 days, they found that seedbed treatments with the greatest disturbance (heavy trampling, land imprinting, and ripping) produced higher emergence than no disturbance or light disturbance treatments. In years where the available soil water was only 2 to 3 days, emergence was low for all seedbed treatments. Winkel and Roundy (1991) suggested that seedbed disturbance may be unnecessary in wet years and provide little benefit for plant establishment in dry years, depending on soil type and seed size of sown species (Winkel and others 1991).

Species Selection

Early revegetation work in southern New Mexico by Bridges, working from 1938 to 1941, determined that the most successful species for revegetation (of the 118 tried) were Rothrock grama (*Bouteloua rothrockii* Vasey), Boer and Lehmann lovegrass, and fourwing saltbush (*Atriplex canescens* (Pursh) Nutt.) (Glendening and Parker 1948). In the semidesert grassland of southern Arizona the best adapted species were Boer, Lehmann, and Wilman lovegrass (Glendening and Parker 1948).

Glendening (1937) conducted and evaluated several revegetation trials at the SRER from 1933 to 1937. These included irrigation, use of mulch, seedbed cultivation, winter seeding, seeding with native hay, seeding with annuals, transplanting, and revegetation using transported topsoil. The following is an overview of this work.

All of the trials were initiated in 1935 except as noted. An irrigated seeding trial used 24 small seedbeds (1 m^2) that were sown to either mixtures or pure stands of the following species: black grama (*Bouteloua eriopoda* (Torr.) Torr.), hairy grama (*B. hirsuta* Lag.), slender grama (*B. repens* (Kunth) Scribn. & Merr), sprucetop grama (*B. chondrosioides* (Kunth) Benth. ex S.Wats), Rothrock grama, sideoats grama (*B. curtipendula* (Michx.) Torr.), and parry grama (*B. parryi* (Fourn.) Griffiths); bush muhly and Arizona cottongrass (cottontop) (*Digitaria californica* (Benth.) Henr.). Plots were sown in early July and hand irrigated for approximately 2 weeks, or until the start of the summer rains. Excellent stands of all the grasses were obtained except black grama and bush muhly. Poor seed quality was the main reason cited for the performance of black grama. After 2 years the established plants were spreading vegetatively. Glendening indicated that if a source of viable seed could be developed black grama would be an excellent species for revegetation due to its ability to persist and spread on poor soils. Glendening considered bush muhly a very poor species to be used in revegetation due to its poor emergence characteristics.

A mulch trial incorporated four (10 by 10 ft) plots that were totally protected from grazing. Plots were seeded to different species after the start of the summer rains. One-half of each plot was covered with 1 inch of barley (*Hordeum vulgare* L.) straw. Grass species used were slender, Rothrock, and sideoats grama; and tanglehead (*Heteropogon contortus* (L.) Beauv. ex Roemer & J.A. Schultes). Seed was applied to the bare undisturbed soil surface. An excellent stand was obtained for each grass plot with mulch. The plots without mulch had little to no emergence or plant establishment (fig. 3). A seedbed cultivation trial was installed in June 1936 prior to the start of the summer rains. A 500-ft^2 plot was seeded to a mixture of Rothrock, slender, and sprucetop grama, and

Mulch trial (1935)

Species	Number of seedlings per square foot[1]							
	Plot I		Plot II		Plot III		Average	
	Littered	Bare	Littered	Bare	Littered	Bare	Littered	Bare
Slender grama	33	0	22	0	26	2	27	1*
Rothrock grama	6	0	5	0	27	0	13	0
Side-oats grama	42	0	39	1*	14	0	32	1*
Tanglehead	3	0	4	0	1	0	1	0
Average							17	1*

[1]Count made 30 days after seed was planted.
*Less than 1 seedling to the square foot.

Figure 3—"Germination upon bare ground and under artificial litter" (Mulch trial 1935; Glendening 1937).

tanglehead, Arizona cottontop, and bush muhly. The plots were hand raked to disturb the soil to a depth of 1 inch, and half of the plot was lightly covered with mulch. Emergence was good despite poor summer rainfall. The mulch-covered portion of the plot had the best emergence, but it was not as dramatic as the previous trial where the seed was sown on the bare soil without disturbance. This trial indicates that cultivation may offset the lack of litter on the soil surface. A similar trial sown in August 1936 compared three treatments: mulch, raked topsoil, and a control. The species from the previously described planting were used in addition to sideoats and black grama. Due to late planting and limited precipitation few plants established. Plots with mulch had the greatest number of seedlings though. A winter seeding trial was sown on December 5, 1935, onto a 2,500-ft^2 plot. The seed mixture included Rothrock, slender, sideoats, and black grama, bush muhly, tanglehead, and Arizona cottontop. The plot had raked and unraked soil surfaces for seedbed treatments. The raked treatment involved cultivating to a depth of about 2 inches, sowing the seed, and then lightly raking to cover the seed. This trial was apparently a failure due to temperatures being too low for germination. This trial was repeated in January 1937 using the same species and treatments with the inclusion of mulch on one-third of the plot. The same results were obtained with no germination or emergence noted.

A native grass hay trial was conducted during the summer of 1936. During 1935 a native grass stand (sideoats, slender, and sprucetop grama, cottontop, and feathergrass (*Chloris virgata* Sw.) was cut when the seed was reaching maturity. The hay was stored and then spread over the study area in 1936. Emergence was good, but plant survival was low by the end of the summer due to below normal summer rainfall. Glendening felt strongly that the use of mulch or grass hay was one of the most promising seeding methods for revegetation of desert rangelands. A winter annual trial included: indianwheat (P*lantago ovata* Forsk.), California poppy (*Eschscholzia californica* Cham.), filaree, fiddleneck (*Phacelia* spp. Juss.), mustards (*Descurainia* spp. Webb & Berth. and *Lepidium* spp. L.), and sixweeks fescue (*Vulpia octoflora* var. *octoflora* (Walt.) Rydb.). Two plantings were conducted (September and October) in 1935 at the Gravelly Ridge site, which is almost due south of the present Continental Grade School on the highway 62. Treatments included the application of mulch over seeds that were sown on bare soil, cultivating the soil prior to sowing, and sowing seeds on bare undisturbed ground. Emergence was good for all treatments due to good November and December rainfall. Rainfall was poor for the months of January through March. The best growth was obtained with the cultivated plot, and the poorest was associated with the bare undisturbed plot.

Glendening's (1937) observations from these SRER trials are summarized below:

Native forage grasses

1. Arizona cottontop, and Rothrock, slender, sprucetop, and hairy grama were the best performers. Black grama, curly mesquite (*Hilaria belangeri* (Steud.) Nash), and bush muhly were typically difficult to establish.
2. Seeding should be conducted at the beginning or just prior to the summer rainy season.
3. Mulch can improve germination, especially on eroded soils. Cultivation and seed incorporation into the soil helps enhance germination but not as much as mulch.
4. Due to erratic precipitation, natural reproduction of native grasses does not occur except in years of average or above average precipitation.

Winter annuals

1. Good stands can be expected from sowing annual species common to Arizona.
2. Winter annuals should be fall planted prior to winter rains.
3. Repeated plantings of annuals should not be required due to their ability to produce seed even during seasons with low precipitation.
4. Cultivation appears to increase germination, but it is not necessary. The application of mulch has no apparent effect on germination but does help overall plant growth.
5. Annuals are generally easy to establish, even on poor soils. Although they can provide some forage they add mulch to the soil that should improve the condition of the soil where grasses could become established.

Glendening (1935) evaluated the use of grass sod in his first transplant trials at the SRER. He indicated that transplanting is a feasible method for small areas but not practical for large areas. Species used in his transplant trial included pearl millet (*Pennisetum glaucum* (L.) R.Br.), bush muhly, tanglehead, Arizona cottontop, poverty threeawn (*Aristida divaricata* Humb. & Bonpl. ex Wild.), small or Santa Rita threeawn (*Aristida californica* Thurb. ex S. Wats var. *glabrata* Vasey), and slender, sideoats, black, and Rothrock grama. Transplants were either dug directly from the field or grown as potted plants. Field-dug plants were placed into flats and taken directly to the trial site and planted (fig. 4). Potted plants were handled the same except plants were taken from the flats and planted into tar-paper pots at the nursery. Potted plants were watered until they were transplanted into the field. It is interesting to note that the potted plant method was considered more time consuming and costly compared to the field-dug plants. Treatments included three planting times (spring, summer, and fall) along with either complete protection from all grazing or protection from livestock grazing only. In June 1935, about

Figure 4—"Small plots 1 by 2 m were transplanted to native grasses. The plants were set out in rows. The rocky nature of the soil made it necessary to use a heavy pick to dig the furrows" (Glendening 1937).

4,000 field-dug plants were transplanted (spring planting) at three study sites on the SRER and irrigated for 3 weeks until the start of the summer rainy season. Transplants were generally planted the same day and never held for more than 24 hours. Five months after transplanting 57 percent of the transplants had established, and 18 months after planting 46 percent of the plants had persisted (fig. 5). The

Species planted	Number planted June 15, 1935	Percentage established November 1935	Percentage survival after 18 months
		percent	percent
Heteropogon contortus	11	100	100
Bouteloua filiformis	266	91	81
Bouteloua chondrosioides	425	72	92
Hilaria belangeri	286	65	23
Aristida californica	325	65	36
Chaetochloa grisebachii	385	64	35
Bouteloua rothrockii	490	61	59
Bouteloua curtipendula	330	60	31
Valota saccharata	350	52	40
Bouteloua eriopoda	725	40	44
Aristida divaricata	350	29	24
Muhlenbergia porteri	70	17	4
Total	4013	57	46

Figure 5—"Percentage of grasses established by transplanting during the spring, with artificial irrigation" (Glendening 1937). *Bouteloua filiformis* syn. *Bouteloua repens*, *Aristida californica* syn. *Aristida californica* var. *glabrata*, and *Valota saccharata* syn. *Digitaria californica*.

summer planting was conducted after the rains started in mid-July 1935 (fig. 6). This planting incorporated three planting sites and 8,500 field-dug plants, which were watered only once at the time they were transplanted. Each planting site had three plots, two with complete grazing protection and one protected from livestock grazing only. Six weeks after planting, one plot was fertilized with a mixture of sodium nitrate and ammonium sulfate. Six months after planting the overall establishment was 58 percent, and after 14 months survival fell to 28 percent. There was no apparent difference between the fertilized and unfertilized plots after 4 months, but after 14 months there was higher survival on the protected unfertilized plots. Plant establishment was much lower on the control plots due to grazing by rodents (fig. 7). The species that had the best establishment on the control plot was tanglehead. Low establishment, for all planting dates and treatments, was believed to be due to low summer rainfall in 1936 followed by a lack of spring precipitation in 1937. Fall transplant trials were initiated in August 1936 and December 1936. Species from the previously described planting were used except the transplants were nursery potted plants. The initial results for the August planting were favorable (fig. 8). Persistence was low, however, due to heavy grazing from rodents that eventually killed the plants. The winter planting met with similar results in that survival and establishment were very low.

Topsoil transplanting was also evaluated by Glendening in 1935 and 1936 at the SRER. Topsoil was removed from well-grassed areas and spread 3 inches deep onto denuded areas where the topsoil had eroded away. Topsoil applications were conducted in July of 1935 and 1936. In both cases fair plant growth was observed. Annuals comprised most of the growth, but a few perennial grasses also germinated and established.

Glendening (1937) summarized his transplanting results as follows:

1. Transplanting of native grasses is feasible under proper weather conditions and can be used to establish perennial

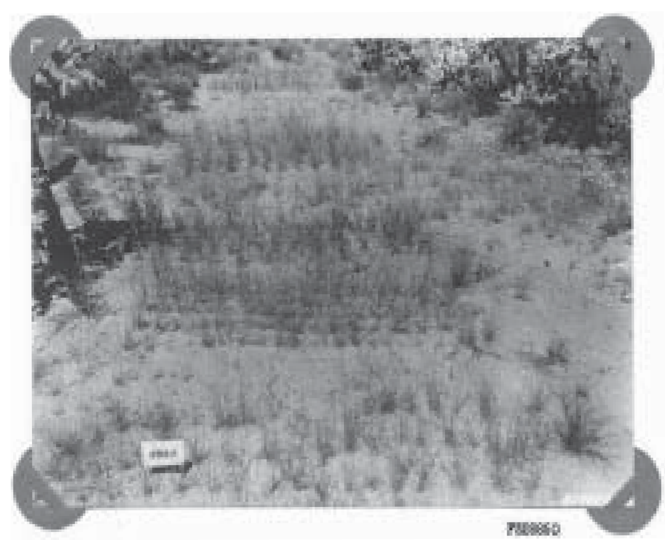

Figure 6—"Grasses transplanted during the summer of 1935 made good growth and many of them set seed during the fall" (Glendening 1937).

-Percentage of grasses established by transplanting during the summer of 1935.

Species	Number planted July 15, 1935				Percentage established November 1935				Percentage survival after 14 months			
	CP[1]	TP[2] fert.	TP[3]	Total	CP	TP fert.	TP	Total	CP	TP fert.	TP	Total
					percent	percent	percent	percent	percent	percent	percent	percent
Bouteloua rothrockii	283	278	299	860	85	90	94	90	5	41	60	36
Valota saccharata	226	161	188	575	65	89	94	81	26	64	86	57
Heteropogon contortus	210	162	171	543	70	67	86	76	40	65	80	62
Bouteloua filiformis	290	288	279	857	64	77	78	73	7	44	58	33
Chaetochloa grisebachii	186	175	181	542	66	61	65	64	11	43	37	30
Bouteloua curtipendula	206	160	168	534	52	64	69	61	12	49	43	33
Muhlenbergia porteri	166	163	164	493	67	52	54	58	11	32	39	27
Bouteloua chondrosioides	315	290	311	916	45	60	47	50	6	27	50	27
Bouteloua eriopoda	296	288	294	878	34	49	44	42	1	35	23	19
Aristida divaricata	231	166	151	548	31	52	44	41	5	17	46	26
Aristida californica	309	290	294	893	49	43	21	38	5	8	14	9
Hilaria belangeri	301	295	302	898	46	29	34	36	0	8	22	20
Total	3019	2726	2802	8537	55	60	59	58	9	32	45	28

1. Protected from cattle grazing
2. Protected from cattle and rodent grazing and fertilized
3. Protected from cattle and rodent grazing but not fertilized.

Figure 7—"Percentage of grasses established by transplanting during the summer of 1935" (Glendening 1937). *Bouteloua filiformis* syn. *Bouteloua repens*, *Aristida californica* syn. *Aristida californica* var. *glabrata, Valota saccharata* syn. *Digitaria californica*, and *Chaetochloa grisebachii* syn. *Setaria grisebachii* (E. Fourn.).

-Percent of grasses established by transplanting during the summer of 1936

	Number planted August 1936			Percentage established April 1937		
	TP	CP	Total	TP	CP	Total
				percent	percent	percent
Trichachne californica	100	50	150	97	96	97
Bouteloua filiformis	200	100	300	74	93	80
Heteropogon contortus	100	50	150	80	64	75
Bouteloua chondrosioides	200	100	300	60	91	70
Aristida californica	200	100	300	60	70	64
Bouteloua rothrockii	200	100	300	47	94	63
Chaetochloa spp.	100	50	150	43	76	54
Aristida divaricata	100	50	150	42	72	52
Bouteloua eriopoda	200	100	300	44	63	50
Bouteloua curtipendula	100	50	150	27	74	43
Hilaria belangeri	200	100	300	13	39	22
Muhlenbergia porteri	100	50	150	12	34	19
Total	1800	900	2700	50	76	58

Figure 8—"Percent of grasses established by transplanting during the summer of 1936" (Glendening 1937). *Bouteloua filiformis* syn. *Bouteloua repens*, *Aristida californica* syn. *Aristida californica* var. *glabrata*, *Trichachne californica* syn. *Digitaria californica,* and *Chaetochloa* spp. syn. *Setaria* spp.

grasses on sites where direct seeding cannot be accomplished successfully.

2. Transplanting should be done in July at the start of the summer rainy season.

3. Direct field transplants have performed as well as potted nursery stock. Potted nursery stock may have some advantages when used in low rainfall areas or on poor soils.

4. Transplanting topsoil from well-grassed areas to badly eroded sites can be successful.

5. Transplanting soil should be done in late spring prior to summer rains to provide the opportunity for perennial grass seed present in the topsoil, to germinate with the summer rains.

6. Topsoil should be acquired from areas supporting grass that naturally reproduce from seed. Sites dominated by curly mesquite and black grama should be avoided due to a lack of a viable soil seed bank.

Glendening installed four trials in the Middle Tank Revegetation Plot, Study Area 205 at the SRER from 1940 to 1948. The four trials were (1) species adaptation, (2) planting methods (discussed under seeding methods), (3) compatible mixture, and (4) grazing (not discussed here).

The species adaptation trial used 50 native and introduced species, mostly grasses. Most of the accessions were acquired from the Tucson Plant Materials Center (table 1). Three treatments were used in this two-replication trial: (1) row plantings, (2) contour furrows, and (3) contour furrows with mulch. The row planting treatment involved hand planting of each species in three 12-ft rows spaced 1 ft apart. The contour furrow treatment used furrows that were 3 to 4 inches deep in 12-ft lengths and on 16-inch centers. Seed was sown and covered by hand. Contour furrows with mulch were installed in the same manner as the contour furrow treatment with mulch applied to the soil surface after seeding. Due to below average rainfall in 1946 and 1947, replanting was done in 1947 and 1948. The May 1949 evaluation indicated that many of the replants failed, especially buffelgrass (*Pennisetum ciliare* (L.) Link). Hall's panic (*Panicum hallii* Vasey) was one of the few replanted accessions found growing in 1949, and African lovegrass (*Eragrostis echinochloidea* Stapf.) and weeping lovegrass (*E. curvula* (Schrad.) Nees) had all but disappeared. Plants survived better on the contour furrows than on the row plantings. The only remaining shrub was rough menodora (*Menodora scabra* Gray). In general, the best performing species were Lehmann, Boer, and Wilman lovegrasses, and Arizona cottontop, and tanglehead (table 2).

A compatible mixture trial evaluated various grasses, mixed with Lehmann lovegrass at different seeding rates or seeded as a single species. The seedbed was prepared by double disking, harrowing to remove plant debris, and installing contour furrows 4 to 6 inches deep at 2-ft intervals. A cyclone seeder was used to broadcast the seed. No seed incorporation treatment was used. Seedings were conducted in July 1946 and repeated in July 1947 due to poor stand establishment from the 1946 planting. The 1947 planting compared Wilman lovegrass, Lehmann lovegrass, and Arizona cottontop at differing seeding rates (table 3a). Comments on the July 1947 planting were that due to below average rainfall this planting had a very poor stand. A second July 1947 planting compared six accessions (Lehmann, Wilman and Boer lovegrasses, and Arizona

Table 1—Species adaptation trials: species list for July 1946 planting. Middle Tank Reseeding Plot, Study Area 205 (adapted from Glendening and others 1946).

Species	SCS accession number
Bothriochloa barbinodis	A 11495
B. ischaemum	A 1407
Dichanthium sericeum (R.Br.)A. Camus	A 11812
Astrebla elymoides Bailey & F.Muell. ex F.M. Bailey	A 1335
A. lapacea (Lindl.) Domin	A 8839
Atriplex canescens	A 5099
A. nummularia Lindl.	A 30
Bouteloua curtipendula	A 2969
B. eludens Griffiths	A 11563
B. eriopoda	A 5066
B. gracilis (Willd. Ex Kunth) Lag. ex Griffiths	A 121424
B. hirsuta	A 10216
B. radicosa (Fourn.) Griffiths	A 11327
Calliandra eriophylla Benth.	A 11672
Chloris berroi Arech.	A 2086
C. cucullata Bisch.	A 2977
Eragrostis bicolor Nees	A 11958
E. brigantha (author not found)	A 620
E. curvula	A 84
E. curvula	A 67
E. echinochloides	A 11960
E. intermedia A.S. Hitchc.	A 8028
E. lehmanniana	A 68
E. lehmanniana var. *ampla* (author not found)	A 11961
E. superba	A 11965
Krasheninnikovia lanata (Pursh) A.D.J. Meeuse & Smit	Commercial
Heteropogon contortus	Number not given
Hilaria belangeri	A 3323
Pleuraphis mutica Buckl.	A 8772
Krameria erecta Willd. Ex J.A. Schultes	A 2284
Leptochloa dubia	A 11695
Lycurus phleoides Kunth	A 10217
Medicago lupulina L.	Commercial 3460
Menodora scabra	A 2408
M. scabra	A 2390
M. longiflora Gray	A 9126
Muhlenbergia porteri	A 2346
Achnatherum hymenoides (B.L. Johnson) Barkworth	A 2691
Piptatherum miliaceum (L.) Coss.	A 1895
Panicum hallii Vasey	A 8002
P. prolutum F. Muell.	A 2664
Pappophorum vaginatum Buckl.	A 8666
Paspalum setaceum Michx.	A 149
Pentzia incana (Thunb.) Kuntze	A 149
Pennisetum ciliare	A 2348
P. orientale (Willd.) L.C. Rich.	A 131
Setaria vulpiseta	A 9051
Sporobolus airoides (Torr.) Torr.	A 920
S. contractus A.S. Hitchc.	A 11569
S. cryptandrus (Torr.) Gray	A 810
S. fimbriatus (Trin.) Nees	A 69 & A 72
S. flexuosus (Thrub. Ex Vasey) Rydb.	A 10117
Digitaria californica	A 8084
Tridens muticus (Torr.) Nash var. *elongatus* (Buckl.) Shinners	A 3014
T. muticus (Torr.) Nash var. *muticus*	A 11321
Erioneuron pilosa (Buckl.) Nash	A 9456
Vicia americana Muhl. ex Willd.	Commercial
V. villosa Roth	Commercial

Table 2—Species adaptation trial and stand rating as of May 1949. Middle Tank Reseeding Plot, Study Area 205 (adapted from Glendening and others 1946).

	Type of planting		
Species	**Flat or row**	**Furrow**	**Furrow and mulch**
Heteropogon contortus	Good	Excellent	Excellent
Eragrostis curvula	None	Very good	Very good
E. superba	Very poor	Good	Good
E. lehmanniana	Fair	Good	Good
E. lehmanniana-Ampla	Poor	Fair	Fair
Pennisetum ciliare	Poor	Good	Poor
Digitaria californica	Fair	Fair	Good
Bothriochloa ischaemum	None	Poor	Poor
Bouteloua repens	None	None	Poor
Panicum hallii	None	None	Poor
Setaria macrostachya	None	None	Poor
Leptochloa dubia	None	None	Trace

Table 3a—Compatible mixture trial, July 23, 1947. Middle Tank Reseeding Plot, Study Area 205 (adapted from Glendening and others 1946).

Species	Seeding rate (lb per acre)	Subplot number
Wilman lovegrass	6	1
Lehmann and Arizona cottontop	3 and 8	2
Wilman and Arizona cottontop	2 and 8	3
Lehmann	3	4
Lehmann and Arizona cottontop	1 and 8	5
Wilman and Arizona cottontop	6 and 8	6
Lehmann and Arizona cottontop	1 and 8	7
Lehmann and Arizona cottontop	3 and 8	8
Wilman	6	9
Wilman and Arizona cottontop	6 and 8	10
Lehmann	3	11
Wilman and Arizona cottontop	2 and 8	12

Table 3b—Compatible mixture trial, July 30, 1947 Middle Tank Reseeding Plot, Study Area 205 (adapted from Glendening and others 1946).

Species	Seeding rate (lbs per acre)	Subplot number
Boer lovegrass	Not shown	A
Arizona cottontop	Not shown	B
Lehmann and Boer and sand dropseed	1, 2, 2	C
Lehmann and Slender grama	_, 3	D
Wilman lovegrass	Not shown	E
Lehmann and slender grama	2, 3	F

cottontop, sand dropseed, and slender grama) at different seeding rates (table 3b). Comments on this July 1947 planting were that a good stand of Lehmann lovegrass and slender grama had emerged, but due to low precipitation in 1948 the established plants for both July 1947 plantings failed to persist (USDA 1947–1948).

In the early 1950s, several plantings were installed in Pasture 140 by H. G. Reynolds, similar to those planted in study area 205 (Reynolds 1952). In July 1951 a three-species mixture trial was sown in Pasture 140. The mixture trial incorporated combinations of Lehmann, Boer, and Wilman lovegrass. The site was cleared of mesquite and the seedbed prepared with the Krause cutaway disc. A hand-held whirlwind seeder was used to broadcast the seed, and all plots were cultipacked. In July 1951, a yield study was planted that used nine different species (table 4). This planting was repeated in July 1952 with minor changes in species used. All species were broadcast seeded followed by a cultipacking. The best performing species was plains bristlegrass (*Setaria vulpiseta* (Lam.) Roemer & J.A. Schultes) because it had better overall emergence. Results for these three plantings were not definitive with comments indicating that all three trials were considered failures. Lack of rainfall in 1951 and 1952 (60 percent of average) was indicated as the primary reason for failure.

Martin (1966) states that based on results from experiments conducted on the SRER the best adapted plants for range revegetation include the introduced species Lehmann, Boer, and weeping lovegrass, and the native species Arizona cottontop, black grama, and sideoats grama with Lehmann and Boer lovegrass considered most reliable. Lehmann lovegrass is considered easier to establish but not as palatable or as long lived as Boer lovegrass. Arizona cottontop, black grama, weeping lovegrass, and sideoats grama were considered viable choices but are more difficult to establish. Weeping lovegrass and sideoats grama are considered suitable for upland sites that receive more moisture or where soils stay moist for a longer period of time. For areas where water accumulates such as swales, blue panic, Johnsongrass (*Sorghum halepense* (L.) Pers.), and Boer, and Lehmann lovegrass are adapted species (Reynolds and Martin 1968). Wilman lovegrass is another suitable species but only in those areas where winter temperatures do not fall below 10 °F. Lehmann lovegrass is generally the only species recommended for upland areas that receive less than 14 inches of precipitation. Martin stated in his 1966 report that adapted species and successful seeding methods have not been developed for areas below 11 inches of annual precipitation (Martin 1966).

Jordan (1981), based on his research conducted in southern Arizona, developed additional criteria to be considered

Table 4—Yield trial-species list, July 11, 1951. Pasture 140 (adapted from Glendening and others 1946).

Species	Accession	Planting rate (lb per acre)
Bouteloua eriopoda	Flagstaff-1949	40
B. repens	A10123-2172	10
Eragrostis bicolor	A11958-ll26	2
E. lehmanniana	A68-2168	1
Heteropogon contortus	SRER 1939	5
Muhlenbergia porteri	A8368	25
Panicum hallii	A8002-2158	3
Sporobolus cryptandrus	Mixed lots 40-41	1
Digitaria californica	A8084-1718-49	12

when selecting species for rangeland revegetation. Included among these were (a) germination rate—species that can germinate in 3 days are better adapted to limited moisture conditions than those species requiring 5 days; (b) species should have good seedling vigor; (c) when revegetation conditions are favorable adapted native species should be used. However, if the site does not have all the favorable conditions, an introduced species may be a better choice; and (d) selected species must be commercially available. A species' commercial availability is directly related to not only its field performance but how much seed it yields, seed production requirements, ease of harvest, seed conditioning requirements, and ability to be sown with currently available equipment. Current research suggests that slower germination, mimicking the conservative germination behavior of Lehmann lovegrass, may improve the potential for emergence and establishment of native species (Abbott and Roundy 2003; Biedenbender and Roundy 1996; Roundy and Biedenbender 1995).

The PMC plantings conducted on the SRER from 1968 through 1970 utilized 12 lovegrass accessions and 2 accessions of buffelgrass and incorporated yellow bluestem (*Bothriochloa ischaemum* (L.) Keng) in the 1969 summer planting. Overall results from these plantings showed that common buffelgrass, T-4464, had the greatest forage production, but it was not significantly higher than the lovegrasses A-1739 and A-17340 or Lehmann lovegrass A-16651, or yellow bluestem. The final evaluation, conducted in 1973, found that "Palar" Wilman lovegrass and a commercial strain of Wilman lovegrass were considered the two best performers in these plantings based on forage production, basal cover, and plant density.

Small observational trials were planted in the fall of 1968, 1969, and 1971. Species were planted using mechanical push planters and seeded into intermediate pits. Sixteen accessions of native and introduced shrubs and forbs were included in these trials. Results from the 1968 and 1969 plantings indicated fair to good overall emergence, but none of the species survived due to dry winters. Two accessions of rough menodora and prostrate kochia (*Kochia prostrata* (L.) Schrad) were sown with two accessions of ballonpea (*Sutherlandia frutescens* (L.) R.Br.). Galleta grass (*Pleuraphis jamesii* Torr.) was included with the above-mentioned species. The final (1979) evaluation indicated that prostrate kochia—A-18219, and rough mendodora—A-17773, from Pomerene, AZ, were the better performers. However, established accessions from both plantings were rated as poor with regard to overall stand, forage production, and erosion control.

In 1980 the PMC installed a summer and fall planting at the PMC planting site on the SRER. The 1980 summer planting included shrubby senna (*Senna corymbosa* (Lam.) Irwin & Barneby), Colorado four o'clock (*Mirabilis multiflora* (Torr.) Gray), spike muhly (*Muhlenbergia wrightii* Vasey ex. Coult.)—A-8604 and "El Vado," green sprangletop (*Leptochloa dubia* (Kunth) Nees), and four accessions of blue panic. Initial emergence and stand were rated as excellent on disked only plots. Due to droughty, loose soil conditions, high plant mortality was observed in this treatment. A September 1982 evaluation indicated that the summer planting of "SDT" blue panic exhibited the highest vigor and stand ratings of the four blue panic accessions planted. The Colorado four o'clock accessions displayed good initial establishment but were no longer evident by the fall of 1982. The 1980 fall seeding exhibited no evidence of emergence or establishment of the seeded species.

In 1983 a total of 18 species of native and introduced grasses, forbs, and shrubs were sown on the SRER at the PMC planting site. Seedbed treatments were intermediate pits and disking. The summer 1983 planting received abundant summer precipitation that resulted in good stands for most of the grasses on both seedbed treatments. As of 1991, "SDT" and "A-130" blue panic, plains bristlegrass, cane bluestem (*Bothriochloa barbinodis* (Lag.) Herter), and yellow bluestem were still exhibiting good stand and vigor ratings.

The PMC installed July plantings in 1985 and 1986 at the SRER site. The 1985 planting consisted of 25 accessions comprised of seven introduced species and nine native species. A transplant trial using African thatchgrass (*Hyparrhenia* spp. Anderss. ex Fourn.) and saltbush (*Atriplex* spp. L.) was installed with this planting. The July 1985 planting exhibited only fair emergence with infrequent establishment of only a few accessions. It was noted that competition from Lehmann lovegrass and common buffelgrass quickly crowded out the established accessions. Rabbits grazed out the saltbush transplants, and only one African thatchgrass accession exhibited significant survival. The 1986 planting revealed no emergence or plant establishment. Low precipitation was considered the reason for this planting failure.

A 1988 planting evaluated the use of "Seco" barley as a mulch cover crop on one-half of the seeding plot and Mediterranean ricegrass (*Piptatherum coerulescens* (Desf.) P. Beauv.) on the other half of the plot. Both accessions were planted approximately ½ inch deep in December 1988 using a grain drill. The barley was planted at a rate of 30 pure live seed (PLS) pounds per acre and the Mediterranean ricegrass at a rate of 2 PLS pounds per acre. By the spring of 1989 only a few barley plants and no Mediterranean ricegrass plants were observed. Lack of sufficient winter precipitation and rodent predation on the barley seed was determined as the primary reasons for this failure.

The USDA Natural Resources Conservation Service, Plant Materials Program is unique among Federal programs in that it can "release" accessions that have superior qualities to commercial growers for public use. The Tucson PMC has released two species that were originally collected on the SRER. "Santa Rita" fourwing saltbush was collected by S. Clark Martin from a native stand on the SRER December 1962. The collection site was T18S, R14E, in section 3 (Tucson Plant Materials Center 1987). "Loetta" Arizona cottontop was collected from a native stand on the SRER by Larry Holzworth in October 1975. The collection site was T18S, R14E, in the southwest ¼ of Section 3 (Tucson Plant Materials Center 2000).

Seeding Methods

In rangeland revegetation, seed is typically sown by broadcasting or by drilling. Both methods have varying degrees of effectiveness depending on condition of the seedbed and seed size. Drill seeding was initially conducted using grain drills, evolving into today's rangeland drills. Prior to the rangeland drill, scientists had to develop their own seeding equipment. Jordan used a modified Nisbet seeder along with modified seed metering plates to plant the tiny lovegrass seeds at recommended rates (Roundy and Biedenbender 1995).

Glendening and others (1946) installed a seeding method trial in 1946 in the Middle Tank Revegetation Plot, Study Area 205, at the SRER. This trial compared the effectiveness of various seedbed treatments and seeding methods using Boer lovegrass. Treatments included two controls (no treatment); mowed, contour-furrowed, and seeded with a two-gang cultipacker with seeder attachment; mowed, contour-furrowed, cultipacked with single-gang cultipacker, and broadcast seeded; and mowed, and cultipacker-seeded only. Evaluations made in 1947 indicated a good stand of Boer lovegrass was obtained with the contour furrow and cultipacker seeder only (USDA 1947–1948). Evaluations made in 1948 indicated that established plants had died due to low precipitation in 1948. A new planting was conducted by Glendening in 1949 that used five seedbed treatments and three seeding treatments with Lehmann and Boer lovegrasses. Imposed on these treatments was a mowing treatment to control burroweed. The five seedbed and seeding treatments were (1) the Krause cutaway disc and cultipacker seeder, (2) Eccentric disc and drill, (3) interrupted furrow and drill, (4) interrupted furrow and broadcast, and (5) no seedbed preparation and broadcast seeding. Results for the 1949 planting indicated that Lehmann lovegrass had better establishment than Boer lovegrass over all treatments. This occurred in the interrupted furrow with drill seeding and interrupted furrow with broadcast seeding. The controlled burroweed plots had twice as many lovegrass plants as the uncontrolled plots.

In 1964 a field trial at the SRER was conducted to compare pelleted and nonpelleted Boer and Lehmann lovegrass seed that was broadcast onto desert rangeland following herbicide application. Pellet size was $\frac{1}{4}$ inch with an average of 10 seeds per pellet, and the pellets were aerially applied at a rate of 62 pounds per acre. On average, there were 1,400 pellets per pound (Chadwick 1964). Chadwick in 1969 summarized the results of the pelleted program. Chadwick found that only one seedling had emerged for every six pellets sown 1 month after sowing, and at the end of September no seedlings were observed, even though the site received over 10 inches of rain during July, August, and September (Chadwick and others 1969). Sowing nonpelleted seed into a prepared seedbed was more successful than broadcasting pelleted seed. Pelleted seeding failed due to lack of good seed soil contact, and the pelleting process actually reduced germination (Roundy and Biedenbender 1995).

All PMC plantings were drill seeded either using a small rangeland drill, push planter (Planet Jr.), or grain drill. Seeding rates were generally based on 20 to 25 (PLS) per ft of row for grasses and 10 PLS per ft for shrubs. Seeding depth was $\frac{1}{4}$ inch for most small-seeded species and up to $\frac{1}{2}$ inch for large-seeded species. The 1971 planting incorporated the use of barley straw for mulch. The site was drill seeded, then the mulch was applied by hand and tucked into the soil using a Soil Erosion Mulch Tiller. The mulch, as well as receiving favorable winter precipitation, provided for good emergence and stand establishment. However, when the final evaluation was conducted in the fall of 1972, only one species, Australian saltbush (*Atriplex semibaccata* R. Br), remained alive.

Summary

The Santa Rita Experimental Range has provided an extensive outdoor laboratory for long-term rangeland revegetation trials on species adaptation, seedbed preparation methods, sowing times and rates, and unique cultural treatments such as mulching. These studies have shown promise with regard to seedbed treatments that enhance plant establishment. Much of the information gained from revegetation trials on the SRER is used in developing the USDA Natural Resource Conservation Service (Arizona) standards and specifications for the Range Planting practice (USDA 2002.)

Seedbed preparation and selection of adapted species are important factors when planning a range revegetation activity. It is evident that timing and amount of precipitation are the primary elements that ultimately determine the success or failure of a planting. Research conducted at the SRER has clearly shown that successful establishment may not indicate long-term persistence. Long-term evaluations on persistence are needed to improve and refine recommendations for range revegetation. Due to costs for brush control, future revegetation activities may leave larger areas of existing woody vegetation, creating the need for identification of shade-tolerant species that can be successfully sown under existing overstory canopies (Livingston and others 1997). Scientists have expanded research efforts to include seedbed ecology, seed germination characteristics, and range plant genetics (Smith 1998; Smith and others 2000). Recent research on the SRER has dealt with germination characteristics and seedbed ecology of Lehmann lovegrass. Results from this research have provided suggestions for managing existing Lehmann lovegrass stands and potential methods, using fire and herbicides, for re-establishing native grasses in Lehmann's dominated areas of the semidesert grassland (Abbott and Roundy 2003; Biedenbender and Roundy 1996; Livingston and others 1997). This additional information and direction can only move us closer to achieving revegetation success. It is interesting to note that early revegetation work used native plants. Unsuccessful plantings with natives led to the search and use of introduced plants such as Lehmann lovegrass. Lehmann lovegrass proved to be very successful, spreading aggressively and reducing biodiversity. Range scientists and others are again working with native plants in the semidesert grassland. This renewed interest in native plants will require research on their germination characteristics, field establishment requirements, and seed production qualities and requirements. Identification of successful establishment characteristics will help to identify native species and or their genotypes for use in revegetation. These species will be used if they are readily available in needed quantities and at an affordable price. The SRER will again provide testing sites for revegetation trials and demonstrations for livestock forage production, erosion control, and improving the biodiversity of plant communities dominated by invasive species.

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