LEHMANN LOVEGRASS (*ERAGROSTIS LEHMANNIANA* NEES.)

ANNOTATED BIBLIOGRAPHY

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This annotated bibliography is an attempt to consolidate and summarize the available literature pertaining to our South African guest, Lehmann lovegrass (*Eragrostis lehmanniana* Nees.). As such, it is a perpetual work-in-progress and our goal is to amend the bibliography whenever new research is published on Lehmann lovegrass. Although we have attempted to be as thorough as possible, we know we have left out many sources; some of these are noted in the "Sources Needed" section at the end of the paper, while others have simply evaded us. If you have copies of literature mentioned in the "Sources Needed" section, or of literature not mentioned or summarized and would like to forward a copy for inclusion in this bibliography, it would be greatly appreciated. Please contact us at researchranch@audubon.org.

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Bold dates in brackets at the beginning of each entry are the years in which the study described took place.

Abbot, L.B., and B.A. Roundy. "Available water influences field germination and recruitment of seeded grasses." *Journal of Range Management*. 56.1 (2003): 56-64.

[1992-93] In a two-year study investigating soil water effects on germination and survival of 6 native and 2 non-native grass species (including Lehmann lovegrass), mesh bags of seed were buried and retrieved during and after the summer rainy season. Although few Lehmann seeds germinated in response to initial or subsequent rainstorms, it retained more residual germinable seeds than any of the other species studied. The ability to retain a viable seedbank even when rainstorms were separated by long, dry periods may allow the species to establish itself better than some natives in the semidesert grasslands of the southwestern United States. [RC]

Albrecht, E.W., E.L. Geiger, A.R. Litt, G.R. McPherson, and R.J. Steidl. "Fire as a tool to restore biodiversity in ecosystems dominated by invasive grasses." *Department of Defense: Legacy Resource Management Program*. 2008.

[1999-2003] Study set out to assess the effects of nonnative grass invasion, fire, and the interaction between grass composition and fire in semi-desert grasslands on plant and animal communities. Areas dominated by Lehmann lovegrass had lower plant diversity than areas dominated by native grasses. Fire only influenced the proportion of Lehmann lovegrass for the first growing season following the fire with no increase 2-3 growing seasons after the fire. It was found that climatic influences affected the proportion of Lehmann lovegrass more so than fire, and thus the removal of fire so as to avoid spread of Lehmann lovegrass may not have the desired effect and may accelerate eradication of native grasses. Disturbances caused by invasion of Lehmann lovegrass represent larger ecosystem alterations and although initial impacts may not appear to have negative impacts, future implications are unknown.

Overall species composition of the small mammal community changed as Lehmann lovegrass dominance increased with granivores and insectivores decreasing and herbivores and omnivores increasing. This may be because both quantity and quality of habitat for many mammal species changed as Lehmann lovegrass increased, leading to increases in vegetation biomass but decreases in heterogeneity. While these changes are beneficial to some species, they are detrimental to others dependent upon habitat preferences. Prescribed fires that aim to mimic natural disturbance regimes and create and maintain a mosaic of structural elements may not prevent or slow the spread of Lehmann lovegrass but it may help to increase structural heterogeneity and maintain diversity and abundance of small mammals.

As Lehmann lovegrass dominance increased, only 5 of 15 grassland bird species showed a response (Botteri's Sparrow, Cassin's Sparrow, and Eastern Meadowlark were affected negatively; Blue Grosbeak and Canyon Towhee were affected positively) while overall abundance increased, as did odds of nesting and density of nests. Regardless of plant community composition, affects of fire on grassland birds appear to be ephemeral with populations recovering within a few years and some ground nesting species able to nest within one year. Fires that maintain a heterogeneous mosaic of successional states and are spaced at least 5 to 10 years apart may be beneficial to species that require sparse vegetation as well as those that require dense vegetation.

Overall abundance of insects and number of insect families and morphospecies present decreased as biomass of Lehmann lovegrass increased, perhaps due to reduced abundance and quality of plant foods and resultant trophic cascades. Effects of fire in nonnative and native grasslands on insects were both complex and unpredictable, although frequency, season, and intensity of fire may be important. Regardless of changes, return to pre-fire levels of abundance and presence is relatively rapid (within one year). [RC]

Anable, M.E., McClaran, M.P., Ruyle, G.B. "Spread of introduced Lehmann lovegrass *Eragrostis lehmanniana* Nees. in Southern Arizona, USA." *Biological Conservation*.61 (1992): 181-188.

[1992] Since its importation into the United States in 1932, Lehmann lovegrass has transformed both the structure and function of at least 145,000 hectares of semi-desert grassland in southern Arizona. Seeded on the Santa Rita Experimental Range (SRER) in 1954, it has since spread to 85% of 75 widely dispersed non-seeded plots and accounted for 40% of all perennial grasses on these plots. Just 16 years after seeding, it represented 50% of all perennial grasses at SRER. Lehmann lovegrass is able to spread without disturbance caused by grazing, can account for 90% of stand biomass, and can produce 3-4 times more biomass than native grasses. At time of publication, USDA Natural Resources Conservation Service and a large majority of federal and state agencies (except US National Park Service, Arizona State Parks Department, and US Forest Service in wilderness areas) promote seeding of Lehmann lovegrass despite aggressive spread and likely faunal impacts (decreased diversity). [RC]

Angell, D.L., and M.P. McClaran. "Long-term influences of livestock management and a non-native grass on grass dynamics in the desert grassland." *Journal of Arid Environments*. 49 (2001): 507-520.

[1972-2000] The objective of this study was to evaluate the long-term, 28-year history of grass dynamics in relation to length of occupation of Lehmann lovegrass in the desert grassland of Arizona. The results suggest that lengthy occupations by Lehmann lovegrass have no influence over the dynamics of native grasses and that any decline in native grasses began before increase in Lehmann lovegrass. There was a relatively stable total density throughout the study period, and it is thought that Lehmann lovegrass simply replaced dead native grasses rather than helping kill them. This replacement may be due to abundance of Lehmann lovegrass seed and germination strategies that allow more successful establishment than natives under highly variable summer rainfalls. The authors expect Lehmann lovegrass to remain dominant and to increase following disturbances such as fire and drought. [RC]

Archer, S.R., and K.I. Predick. "Climate change and ecosystems of the southwestern United States." *Rangelands*. 30.3 (2008): 23-28.

[2008] Because many of their resident species live near the physiological limits for water and temperature stress, arid ecosystems in the southwestern United States are extremely susceptible to climate change and variability. Furthermore, exotic species benefit from disturbances caused by climate such as droughts and floods, events likely to increase in number and severity in the future. The success of Lehmann lovegrass in the Sonoran Desert and its forays into the Chihuahuan Desert appear to be due in part to its seedling drought tolerance and ability to more effectively utilize winter moisture. The spread of Lehmann lovegrass in the southwestern United States appears to be due more to wet periods associated with the Pacific Decadal Oscillation than with increases in Nitrogen-deposition or carbon dioxide concentrations. [RC]

Biedenbender, S.H., M.P. McClaran, and B.A. Roundy. "Effects of neighbor species and distance on 2- and 4-year survival of Lehmann Lovegrass and native grasses." *USDA Forest Service Proceedings*. RMRS-30 (2003)

[1994-98] This two-pronged study aimed to compare the survival rates of Lehmann lovegrass with two native grasses (plains lovegrass and Arizona cottontop) as well to determine if Lehmann lovegrass, as a same aged neighbor, affected the native grasses differently than same-species neighbors. One year after establishment at the Santa Rita Experimental Range survival rates were 92% for plains lovegrass, 90% for Arizona cottontop, and 92% for Lehmann lovegrass. Two years after establishment, survival rates were 10% for plains lovegrass, 30% for Arizona cottontop, and 76% for Lehmann lovegrass. Four years after establishment, survival rates were zero for plains lovegrass, 16% for Arizona cottontop, and 60% for Lehmann lovegrass.

After two years, plains lovegrass mortality was higher with same-species neighbors than with no neighbors or Lehmann lovegrass neighbors and Arizona cottontop mortality was highest with Lehmann lovegrass. After four years, all plains lovegrass died regardless of neighbor; Arizona cottontop had 60% survival with no neighbors and 0% survival with Lehmann lovegrass neighbors; Lehmann lovegrass had 8% survival with no neighbors, and 50% survival with native neighbors. These results suggest that the intensity of competition between Lehmann lovegrass and selected native grasses increases over the first 4 years. [RC]

Biedenbender, S.H. and B.A. Roundy. "Establishment of native semidesert grasses into existing stands of *Eragrostis lehmanniana* in southeastern Arizona." *Restoration Ecology*. 4.2 (1996): 155-162.

[1992-94] To examine native grass restoration in southern Arizona, seven native species – cane beardgrass (*Bothriochloa barbinodis*), sideoats grama (*Bouteloua curtipendula*), Arizona cottontop (*Digitaria californica*), green spangletop (*Leptochloa dubia*), bush muhly (*Muhlenbergia porteri*), bristlegrass (*Setaria leucopila*), and plains bristlegrass (*S. macrostachya*) – were direct seeded into Lehmann lovegrass stands that were either left alive, burned, sprayed with an herbicide and left standing or sprayed with herbicide and mowed. Native grass establishment depended mainly on post-sowing precipitation and water availability. Pre-rainy season June plantings were initially successful 1 out 3 years, while mid-rainy season August plantings were initially successful 2 out of 3 years. Regardless, second-year persistence was limited for all treatments. The least intensive method for native re-establishment would be to burn Lehmann lovegrass in June and seed native grasses before or during the rainy season. This can be risky as rainfall patterns might give Lehmann lovegrass an advantage over the native grasses. A more intensive yet less risky approach involves an initial treatment such as burning, which forces expression of the seed bank, followed by a second treatment, such as herbicide application, which kills the Lehmann lovegrass seedlings, and then direct seeding of natives, with repeated sowing in August of the same year or during the following rainy season. [RC]

Billy, B.J, J.L. Stroehlein, and Ogden, P.R. "Response of Lehmann lovegrass to time of fertilizer application." *Journal of Range Management*. 26.3 (1973): 222-224.

[1967-68] Lehmann lovegrass production increased three fold in the southern Arizona desert grassland following application of 30-10-0 fertilizer as late as July 22. Later application dates showed much smaller seed yields. Immediately following fertilization, available phosphate and nitrate-nitrogen in the top 4" of soil increased, but this was followed by a rapid decrease in nitrate-nitrogen. Plots fertilized after sufficient rainfall and growth period of grass begins generally reach peak yield and have higher nitrogen and phosphorous contents later and remained greener in the fall months than the plots treated early in the rainy season. [RC]

Bock, C. E.; Bock, Jane H. "Factors controlling the structure and function of desert grasslands: a case study from southeastern Arizona." In: Tellman, B., Finch, D.M., Edminster, C., Hamre, R. editors. *The future of arid grasslands: identifying issues, seeking solutions*. RMRS-P-3. 1996 October 9-13; Tucson, Arizona. Fort Collins, CO: USDA Forest Service; 1996. 33-44.

[1974-1996] This study examined the structure and functioning of southeastern Arizona desert grasslands as well as the effects of livestock grazing, fire, drought and establishment of non-native grasses on the structure and functioning of desert grassland ecosystems. Comparisons of three sites dominated by *Eragrostis* spp. (Lehmann lovegrass and Boer lovegrass) and similar areas lacking these grasses have shown that the introduction and spread of *Eragrostis* spp. leads to significant reductions in native biodiversity. Once established, *Eragrostis* spp. and especially Lehmann lovegrass are able to spread rapidly and quickly come to dominate an area. Solid, near monotypic stands of *Eragrostis* spp. crowd out most native plants and tend to support a greatly reduced variety and abundance of native wildlife. Native grasses, native herbs, burro weed, groundsel, loggerhead shrike, horned lark, Cassin's sparrow, grasshopper sparrow, eastern meadowlark, savannah sparrow vesper sparrow, hispid pocket mouse, pygmy mouse, western harvest mouse, and nine species of grasshopper have been shown to decrease in areas dominated by *Eragrostis* spp., while only fulvous cotton rat, Botteri's sparrow, and one species of grasshopper increase. The benefits associated with *Eragrostis* spp. (increased forage, soil stability) do not outweigh the negative impacts it has on native flora and fauna. In areas protected from livestock grazing since 1968, natives do not appear to be replacing *Eragrostis* spp., which exemplifies the African grasses ability to invade areas undisturbed by grazing. [RC]

Bock, C.E., and J.H. Bock. "Grassland birds in southeastern Arizona: impacts of fire, grazing, and alien vegetation." *Ecology and Conservation of Grassland Birds.* Ed. P.D. Goriup. International Council for Bird Preservation Technical Publication No. 7, 1988. 43-58.

[1984-85] Drought and overgrazing in the late 1800's severely impacted southwestern grasslands, which have not yet completely recovered due to the continued presence of livestock, disruption of the natural fire regime, and introduction of exotic grasses such as *Eragrostis* spp. (including Lehmann lovegrass). Livestock grazing and disturbance of the fire regime both aid the spread of *Eragrostis* spp., creating a complex web of interactions among these disturbances. Areas of *Eragrostis* spp. domination are largely absent of native grasses, herbs, and shrubs, and grasshoppers are half as abundant in these areas as in native plots. Compared to ungrazed native vegetation, ungrazed *Eragrostis* spp. areas produce less seeds and do not provide habitat for insects, two major food sources for grassland birds. As a result, the *Eragrostis* spp. invaded areas tend to be ornithologically sterile with only one species preferring these areas – Botteri's sparrow. Far superior habitat for grassland birds is provided by native plots with a more heterogeneous mixture of plant species and greater availability of food by way of seed and insects. [RC]

Bock, C.E. and J.H. Bock. "Response of birds to wildfire in native versus exotic Arizona grassland." *The Southwestern Naturalist*. 37.1 (1992): 73-81.

[1984-90] In the midst of a study of 25 native grassland plots and 25 plots invaded with *Eragrostis* spp. including Lehmann lovegrass, a wildfire in July of 1987 burned 11 plots of each, allowing the authors to evaluate the consequences of a natural burn in the southeastern Arizona grassland. The abundance of birds recorded in the fall increased dramatically on both the burned native and the burned exotic plots, most likely because of increased seed production and availability. Mourning dove (*Zenaida macroura*), horned lark (*Eremophila alpestris*), vesper sparrow (*Pooecetes gramineus*), and savannah sparrow (*Passerculus sandwicensis*) were the dominant species attracted to the burn areas. Grasshopper sparrow (*Ammodramus savannarum*), Botteri's sparrow (*Aimophila botterii*), Cassin's sparrow (*Aimophila cassinii*), and eastern meadowlark (*Sturnella magna*) avoided the burned plots. Although the effects of the fire were ephemeral and there was no evidence that the burn facilitated a switch to more native species, there is evidence that the burn did make exotic grasslands more suitable for certain birds recorded in summer through reduction of otherwise heavy accumulations of litter. [RC]

Bock, C.E., J.H. Bock, K.L. Jepson, and J.C. Ortega. "Ecological effects of planting African lovegrasses in Arizona." *National Geographic Research*. 2 (1986): 456-463.

[1984-85] Studied the impact of African lovegrasses (Lehmann lovegrass and weeping lovegrass) on native flora and fauna of a southeastern Arizona grassland preserve ungrazed since 1968. Results show that areas dominated by *Eragrostis* spp. tend to be biologically sterile compared to stands of native grasses, with a greater abundance and variety of native plants and animals on the native plots. Only three native species were found to be more abundant in the *Eragrostis* spp. infested areas (Arizona cotton rat, Botteri's sparrow, and the *Phoetaliotes nebrascensis* grasshopper). For at least the sparrow and the rat, *Eragrostis* spp. stands most likely mimic the native sacaton grassland where they normally occur. In areas where *Eragrostis* spp had been planted, they covered more than 50% of the ground and native grass cover was reduced by nearly 60%. Grasshoppers, the dominant insect group in the grassland, were reduced by 44% in stands of *Eragrostis* spp.. In both winter and summer, birds as a group were detected more often in native stands than in *Eragrostis* spp. stands with the exception of Botteri's sparrow. Stands of *Eragrostis* spp. housed a greater abundance of rodents than native stands, although this result was entirely due to the abundance of Arizona cotton rat, a grazing rodent (most other species feed mainly on seeds or invertebrates). Twenty-six species (10 plants, 5 birds, 3 rodents, and 8 grasshoppers) were significantly more abundant on native grassland than *Eragrostis* spp. dominated areas. The authors note that in certain, severely damaged southwestern grasslands for which recovery is unlikely *Eragrostis* spp. may at least be able to provide soil stability and minimal wildlife habitat, but otherwise the effects of *Eragrostis* spp. planting are ecologically detrimental. [RC]

Bock, C.E., J.H. Bock, L. Kennedy, and Z.F. Jones. "Spread of non-native grasses into grazed versus ungrazed desert grasslands." *Journal of Arid Environments*. 71 (2007): 229-235.

[1984-2006] Studied canopy cover of native and exotic (Lehmann lovegrass and Boer lovegrass) grasses over a period of 22 years on grazed and ungrazed grasslands to determine whether livestock grazing is an exogenous disturbance facilitating spread of exotic grasses. Both treatment sites were located in southeastern Arizona and the ungrazed plots had not been grazed since 1968. In 1984, the exotic grasses made up <1% of total grass canopy in both plots. 22 years later they had spread to comprise 24% in the ungrazed plots, and to 65% on grazed plots. Over the same time period, both exotic *Eragrostis* spp. grasses had increased from 79% to 99% canopy in ungrazed areas where they were planted. These results suggest that the rate of exotic invasion is reduced where livestock grazing does not occur; that when planted, *Eragrostis* spp. will develop into a monoculture with or without grazing; and livestock grazing is indeed an exogenous disturbance in southeastern Arizona to which *Eragrostis* spp. is better adapted than native grasses. This could be because *Eragrostis* spp. evolved in the presence of native ungulates in its native habitat (South Africa), whereas native southeastern Arizona grasses have not been affected by native ungulates since the Pleistocene era when Bison roamed the area. [RC]

Bock, J.H., and C.E. Bock. "Exotic grasses and native wildlife." *Sonorensis* Winter 2002: 27.

[1984-1990] A mid 1980's comparison of plants, birds, small mammals, and grasshoppers inhabiting areas of native grasses and those dominated by *Eragrostis* spp. (Lehmann lovegrass and weeping lovegrass) in southeastern Arizona. Plant diversity was decreased with native grasses, wildflowers, and shrubs missing or scarce in the *Eragrostis* spp. stands. Only native mesquite trees did well in both stands. With the exception of Botteri's sparrow, summer birds favored areas of native grasses over *Eragrostis* spp. areas. Similarly, only one species of rodent, the Arizona cotton rat preferred *Eragrostis* spp. infested areas while most native residents were absent. Native grass plots also had twice as many kinds of grasshoppers than did *Eragrostis* spp. dominated areas, and the authors note, even cattle prefer native grasses over *Eragrostis* spp.. [RC]

Bock, J.H. and C.E. Bock. "Vegetation responses to wildfire in native versus exotic Arizona grassland." *Journal of Vegetation Science*. 3 (1992): 439-446.

[1984-1990] In a study of grass and herb cover, and woody plant densities, 25 native plots and 25 exotic plots (seeded 40 years prior with Lehmann lovegrass) in southeastern Arizona were monitored from 1984 to 1990. In 1987, a wildfire burned 11 of each plots. Both native and exotic grasses appeared to be equally tolerant of fire as they both recovered and the study found no evidence that fire can be used to permanently restore the diverse native flora to areas dominated Lehmann lovegrass. [RC]

Brooks, M.L. and T.C. Esque. "Alien grasses in the Mojave and Sonoran deserts." *Proceedings of the California Exotic Pest Plant Council Symposium* 6 (2000): 39-44.

[2000] Both annual and perennial alien grasses have invaded the Mojave and Sonoran deserts. Dominant perennials include buffelgrass (*Pennisetum ciliare*), Natal grass (*Rhynchelytrum repens*), and Lehmann lovegrass. Alien perennials tend to be less tolerant of frost and require larger amounts of summer rainfall than annuals, which may explain why they have not spread further north into the Mojave than they have. Alien grasses facilitate the spread of fire, can thrive in post fire landscapes, and their shortened fire return interval can pose serious threats to native plants and animals. Furthermore, these grasses are able to compete with native plants for nutrients and reduce native productive potential and possibly diversity. Due to the ecological damage caused by these species as well as the difficulty of control of established populations, early control of populations is critical. At the time of publication, Lehmann lovegrass was not present in California. [RC]

Brown, J.H., and E.J. Heske. "Control of a desert-grassland transition by a keystone rodent guild." *Science*. 250.4988 (1990): 1705-1707.

[1977-89] To determine the effects of removal of a keystone guild, a species of kangaroo rat (*Dipodomys* spp.) was removed from a Chihuahuan Desert shrub habitat. Twelve years after removal the desert had transitioned to grassland and the density of annual and perennial grasses had increased threefold with Lehmann lovegrass increasing more than 20-fold. The results indicate that through seed predation and soil disturbance, keystone guilds can have major impacts on biological diversity and biogeochemical processes. Kangaroo rats exhibit selective foraging for large seeds, which may explain the dramatic increase in the small seeded Lehmann lovegrass. [RC]

Burson, B.L., and P.W. Voight. "Cytogenic relationships between the *Eragrostis curvula* and *E. lehmanniana* complexes." *International Journal of Plant Sciences*. 157.5 (1996): 632-637.

[1996] To gain a better understanding of the relationships within and between the Lehmann lovegrass and weeping lovegrass (*E. curvula*) complexes, the meiotic chromosome pairing behavior between diploid and tetraploid cytotypes of weeping lovegrass, Boer lovegrass (*E. curvula* var. *conferta* Nees.), and Lehmann lovegrass were analyzed. Cytotypes with 20, 30, and 40 chromosomes have been reported for Lehmann lovegrass. Poyploid cytotypes reproduce by diplospory, diploids are sexual, and apomixis has contributed to the diversity of types in Lehmann lovegrass. Lehmann lovegrass and Boer lovegrass appear to have similar genomes and share a common ancestry. Although these two complexes have similar genomic constitution and could be considered one, research has shown them to be genetically isolated and best treated as separate species. [RC]

Cable, D.R. "Damage to Mesquite, Lehmann lovegrass, and Black Grama by a hot June fire." *Journal of Range Management*. 18.6 (1965): 326-329.

[1963] An accidental June 23 fire at the Santa Rita Experimental Range allowed for the author to obtain data on the effects of fire on Velvet mesquite (*Prosopis juliflora*), black grama (*Bouteloua eriopoda*), and Lehmann lovegrass. The burn area consisted of half nearly pure stands of Lehmann lovegrass, half mixed native grasses dominated by black grama, had not received precipitation for 64 days, and had existent grass clumps that were mostly dried with few wilted green leaves. The fire killed 25% of the mesquite trees in the areas dominated by Lehmann lovegrass, while 8% were killed in the black grama area. 10% of the burned black grama sprouted after the fire while only 2% of the Lehmann lovegrass did so, Lehmann lovegrass established itself with new seedlings on both plots the following summer. On the Lehmann lovegrass dominated plots, density of new Lehmann lovegrass was over six times that of the original stand and nearly as many new Lehmann lovegrass plants had established themselves on the black grama plots. [RC]

Cable, D.R. "Lehmann lovegrass on the Santa Rita Experimental Range, 1937-1968." *Journal of Range Management*. 24.1 (1971):17-21.

[1937-1968] Originally seeded on the Santa Rita Experimental Range (SRER) in 1937, Lehmann lovegrass was used for numerous revegetation trials between 1945 and 1954. Eight factors have been attributed to Lehmann lovegrass following 30 years of observation at the SRER. 1) During summer growing seasons Lehmann lovegrass is less palatable than native perennial grasses; 2) in areas where it is well adapted (3,400' to 4,100' elevation and 13"-17" of annual rainfall) it will eventually dominate a stand and drastically reduce native grasses; (note: at lower elevations and with 13" or less of rainfall, Lehmann lovegrass will persist in scattered stands, but does not pose a threat to native perennials) 3) easily becomes established under adverse conditions; 4) reseeds quickly following fire or other disturbance; 5) is able to invade stands of Velvet mesquite (*Prosopis julifora* var. *velutina*); 6) able to carry herbage from one year to the next in better physical condition than natives; 7) produces more green herbage during winter and early spring than native perennials; and 8) is able to withstand repeated close grazing. [RC]

Cable, D.R. and J.W. Bohning. "Changes in grazing use and herbage moisture content of three exotic lovegrasses and some native grasses." *Journal of Range Management*. 12.4 (1959): 200-203.

[1956-57] Seeded and grazed plots of Lehmann lovegrass, Boer lovegrass (*Eragrostis chloromelas*), and Wilman lovegrass (*E. superba*) on the Santa Rita Experimental Range were studied to determine relationship between grazing and moisture content of herbage, season of highest palatability, and palatability compared with natives. There was no relationship between grazing use and herbage moisture content for any of the grasses studied. Lehmann lovegrass was grazed preferentially during the late spring, and cattle preference among the grasses studied differed depending on the season. [RC]

Cable, D.R. and F.H. Tschirley. "Responses of native and introduced grasses following aerial spraying of velvet mesquite in southern Arizona." *Journal of Range Management*. 14.3 (1961): 155-159.

[1954-1959] Velvet mesquite (*Prosopis juliflora*) has begun to invade the southeastern Arizona rangelands during the past 60 to 75 years following decades of overgrazing and has caused the loss of sizable portions of native perennial cover. From 1954 to 1959 on the Santa Rita experimental range, herbage production of native perennial grasses and Lehmann lovegrass were compared on sprayed and unsprayed portions of a Velvet mesquite infested pasture. Herbage production for native perennials averaged almost twice as much on the sprayed pastures as on the unsprayed, while Lehmann lovegrass averaged almost three times as much on the sprayed as on the unsprayed. Slow rate of Velvet mesquite recovery implies the treatment won't have to be applied often. [RC]

Cox, J.R. "Lehmann lovegrass live component biomass and chemical composition." *Journal of Range Management*. 45.6 (1992): 523-527.

[1984-1986] Study to determine the production and chemical composition of live Lehmann lovegrass leaves, culms, and seedheads during wet and dry years. Green leaf biomass peaked in early August, culms peaked in mid October, and green seedheads peaked in mid August. Leaf and culm growth peaks correspond with low crude protein and moderate phosphorous levels, while seedhead growth peaks correspond with high crude protein and moderate phosphorous levels. As Lehmann lovegrass invades southeastern Arizona, it is important to determine how this invasion will affect biomass production and quality; this study shows that Lehmann lovegrass crude protein will meet animal requirements for about half the year and phosphorous requirements throughout the year. [RC]

Cox, J.R. "Temperature, timing of precipitation and soil texture effects on germination, emergence and seedling survival of South African lovegrasses." *South African Journal of Botany*. 50.2 (1984): 159-170.

[1983] The germination, emergence, and seedling survival of three South African lovegrasses (Lehmann lovegrass, Atherstone lovegrass {*Eragrostis atherstone* Stapf.}, and Boer lovegrass {*E. curvula* var. *conferta* Nees.}) and a genetically selected accession (Catalina Boer lovegrass) from parent plants originally collected in South Africa were evaluated at different temperatures, under different initial precipitation regimes, and in three soils common to the southwestern United States. Catalina Boer lovegrass seed germinated over a wider range of temperatures, from greater soil depths, and Catalina

Boer seedlings were more drought tolerant than were those of the Lehmann, Atherstone, or Boer lovegrasses. The findings show that Lehmann lovegrass germination is inhibited by cool temperature, its emergence is slow, and seedlings are not drought tolerant and must be planted near the soil surface, which dries rapidly in summer. [RC]

Cox, J.R., M. Giner-Mendoza, A.K. Dobrenz, and M.F. Smith. "Defoliation effects on resource allocation in Arizona cottontop (*Digitaria californica*) and Lehmann lovegrass (*Eragrostis lehmanniana)*." *Journal of the Grassland Society of South Africa*. 9.2 (1992): 53-59.

[1991] Arizona cottontop (*Digitaria californica*), a bunchgrass native to the Chihuahuan and Sonoran Deserts, and Lehmann lovegrass were defoliated and examined for above- and below-ground productivity, nitrogen and phosphorus allocation, as well as photosynthetic potential. Following defoliation, Arizona cottontop re-established a canopy faster than Lehmann lovegrass with the differences due to greater numbers and growth rate of Arizona cottontop leaves. Lehmann lovegrass, although tolerant of grazing, has a lower investment in above- and below-ground biomass, nitrogen, and phosphorus per plant, showing that this tolerance may be more related to Lehmann lovegrass' dense, shallow root system and prostrate form of leaves. [RC]

Cox, J.R., F.A. Ibarra-F, and M.H. Martin-R. "Fire effects on grasses in semiarid deserts." Effects of fire management of southwestern natural resources. Ed. J.S. Krammes (tech coord). 1990.

[1985-87] To determine if, as with tall-grass prairies, fire does not affect perennial grasses in the semidesert grasslands, Cox et al. burned both native and introduced grasslands to determine seasonal fire effects on them. Three sites were chosen, one in Carbo, Mexico, the other two in Arizona at the Santa Rita Experimental Range (SRER) and the Empire Ranch. The SRER was the only site where Lehmann lovegrass was the dominant grass. Forty-five 15 by 15 m plots at SRER were burned with a head fire in February, June, or October and Lehmann lovegrass leaves appeared within 14 days after each burn. Observations indicate that while below freezing temperatures kill Lehmann lovegrass plants burned in fall, seed germination is stimulated the following summer. The first summer following fall burns, Lehmann lovegrass green herbage was less than those areas that were unburned or burned in winter, spring, and summer, but total green herbage production equaled or exceeded that on summer, spring or winter burns after three years. Results show that fire in semidesert grasslands can adversely affect perennial herbage production for 2 to 3 years. [RC]

Cox, J.R., and G.L. Jordan. "Density and production of seeded range grasses in southeastern Arizona (1970-1982). *Journal of Range Management*. 36.5 (1983): 649-652.

[1970-1982] Lehmann lovegrass and nine other range grasses (including four Lehmann lovegrass accessions) were seeded at a study site near San Simon, Arizona in spring 1970 and 1971. The beds were prepped by root plowing and furrow pitting just before planting. Growing season precipitation was 136 mm in 1970 and 218 mm in 1971. In the 1970 plantings, Lehmann lovegrass had the greatest initial stand density (25 plants/m^2) but had a density of less than 0.2 plants/m^2 by 1982, while the overall high was 1 plant/m^2. Among the 1971 plantings, Lehmann lovegrass again had the greatest initial stand density (25 plants/m^2) but by 1982 was down to 4 plants/m^2, while overall high was 5 plants/m^2. Observations suggest that germination and emergence follow single storms or groups of closely spaced storms dropping 20 mm or more, and that emergence occurs in late July and August. [RC]

Cox, J.R., and R.M. Madrigal. "Establishing perennial grasses on abandoned farmland in southeast Arizona." *Applied Agricultural Research*. 3.1 (1988): 36-43.

[1980-83] As a result of falling water tables and the transfer of water rights from agricultural to urban uses, several hundred thousand hectares of semidesert grassland converted to agriculture in southeastern Arizona were abandoned by 1980. This study aimed to determine the effects of planting season, amount of irrigation water, and competition on the establishment and forage production of seven perennial grasses including Lehmann lovegrass and two Lehmann lovegrass accessions on Pima silty clay loams. None of the Lehmann lovegrass varieties emerged regardless of planting season, irrigation amount, or lack of weed competition. [RC]

Cox, J.R., R.M. Madrigal, and G.W. Frasier. "Survival of perennial grass transplants in the Sonoran Desert of Southwestern Arizona." *Arid Soil and Research Rehabilitation*. 1 (1987): 77-87.

[1980-82] In a 3-year study of six groups of similar perennial grasses (including Lehmann lovegrass and Cochise lovegrass (*Eragrostis lehmanniana* x *E. trichophora*)), nine-week-old seedlings were transplanted to coincide with summer and winter precipitation and were evaluated biannually to compare survival. Average survival throughout the study was 73% at 2 months and 39% at 32 months following the summer transplanting. Lehmann lovegrass averaged the highest survival rate (64%) for 32 months after summer transplanting. Cochise lovegrass was the only grass to survive the 3 winter plantings. Study results show that successful transplants should only be made following the summer rainy season if establishment is desired. Results also demonstrated that Lehmann lovegrass consistently emerge only from sandy loam soils, germination is slow (48-120 hours), seedlings are not drought tolerant, and seed must be planted near the soil surface that dries rapidly in summer. [RC]

Cox, J.R., and M.H. Martin. "Effects of planting depth and soil texture on the emergence of four lovegrasses." *Journal of Range Management*. 37.3 (1984): 204-205.

[1982] Four lovegrass accessions were planted at 0.0, 0.5, 1.0, 1.5, and 2.0 cm depths in Pima silty clay loam, Sonoita silty clay loam, and Comoro sandy loam soils in a greenhouse. Lehmann lovegrass failed to emerge from when planted below the surface in any of these these soils and must be surface sown in order to emerge. [RC]

Cox, J.R., M.H. Martin-R, F.A. Ibara-F, J.H. Fourie, N.F.G. Rethman, and D.G. Wilcox. "Effects of climate and soils on the distribution of four African grasses." Proceedings of Symposium "Seed and Seedbed Ecology of Rangeland Plants." 1988.

[1987] This study aimed to determine the climatic and edaphic characteristics of areas where invasive species are native and where they have now been established, as well as the characteristics that influence long-term persistence. Between 1937 and 1950, approximately 135 kg of Lehmann lovegrass seed were produced in Tucson and planted in small plots from west Texas to Arizona. Following success in these plots, commercial seed growers produced more than 75,000 kg of Lehmann lovegrass seed, most of which was sown in Arizona, New Mexico, and Texas with the remainder going to the northern frontier states of Mexico. By 1980 Lehmann lovegrass had been established on more than 70,000 hectares in the Southwestern U.S. and northern Mexico and had spread by seed to an additional 70,000 hectares. Areas of Lehmann lovegrass dominance in South Africa range in elevation from 1,175 and 1,350 m, with daily temperatures varying from 0°C to 19°C and 18°C to 34°C, and approximately 80% (225 to 395mm) of annual rainfall comes in late spring, summer, and fall with a peak in late summer. Rainfall during its active growing period ranges from 130 to 160 mm. Areas of establishment in North America range in elevation from 775 to 1,540 m, with daily temperatures varying from -4°C to 20°C and 13°C to 38°C respectively, and annual rainfall ranging from 275 to 500 mm distributed in a summer peak or bimodally in summer and winter. Lehmann lovegrass will self-seed and spread in areas where rainfall during its active growth period is from 150 to 220 mm; it will persist but not spread with approximately 100 mm of rainfall during its active growth period; and established stands will die with rainfall during its active growth period ranging from 70-85 mm. Lehmann lovegrass seedlings emerge only when planted near the surface of sand, loamy sand, and sandy loam soils and its spread is thought to be limited to loamy sand and sandy loam soils. [RC]

Cox, J.R., M.H. Martin, F.A. Ibara-F, J.H. Fourie, N.F.G. Rethman, and D.G. Wilcox. "The influence of climate and soils on the distribution of four African grasses." *Journal of Range Management*. 41.2 (1988): 127-139.

See Cox et al. 1988 *above.*

Cox, J.R., M.H. Martin-R., F.A. Ibara-F., and H.L. Morton. "Establishment of range grasses on various seedbeds at creosotebush (*Larrea tridentata*) sites in Arizona, USA, and Chihuahuan, Mexico." *Journal of Range Management*. 39.6 (1986): 540-546.

[1981-82] At four sites invaded by creosotebush (*Larrea tridentata*) in the semidesert grassland, Cochise lovegrass (*Eragrostis lehmanniana* X *E. trichophera*) and Catalina Boer lovegrass (*E. curvula* var. *conferta*) were seeded by drilling or broadcasting. Seedbeds received one of four mechanical treatments and one of three chemical treatments. Both grasses were established and persisted in 6 of the 8 disk plowed and disk plowed/contoured furrowed seedbeds. Both were also established and persisted in 2 of the 5 beds treated with tebuthiuron at 0.5, 1.0, and 1.5 kg a.i/ha rates. Both grasses were established on land that was railed and imprinted but died within 3 to 4 years. [RC]

Cox, J.R., H.L. Morton, T.N. Johnsen, Jr., G.L. Jordan, S.C. Martin, and L.C. Fierro. "Vegetation restoration in the Chihuahuan and Sonoran Deserts in North America." *Rangelands*. 6 (1984): 112-115.

[1984] Artificial seeding of the southwestern United States and northern Mexico has been an ongoing effort since changes brought about by overgrazing in the late 1800's. More than 300 forb, grass and shrub species have been planted, and eighty-three species are recommended for rangeland use. Some recommendations are based on premature results, infrequent observations, poorly conducted experiments, and atypical data collection. Following, the authors found that 10 species can consistently be established at locations within the Chihuahuan and Sonoran deserts. Eight are introduced grasses, one is native grass (Green sprangletop), and one is a native shrub (Fourwing saltbush). The most widely adapted species of these are all lovegrasses: Boer lovegrass, Catalina Boer lovegrass, Cochise lovegrass, and Lehmann lovegrass. [RC]

Cox, J.R., J.M. Parker, and J.L. Stroehlein. "Soil properties in Creosotebush communities and the relative effects on growth of seeded range grasses." *Soil Science Society of America Journal*. 49.6 (1984): 1442-1445.

[1982] Soil samples were collected from the canopy center, along the outer canopy edge, and the open spaces between canopies of 10 creosotebush (*Larrea tridenta*) plants at five sites in the southwestern United States. Soils were analyzed for particle size, distribution, pH, EC, $CaCO^3$, Ca, K, Na, Mg, NO^-_3-N, organic C, available P, and Mn, before being seeded with Lehmann lovegrass and blue panicgrass (*Panicum antidotale* Retz.). In both species seedlings were stunted, foliage was yellow, and the heights and total plant biomass were significantly less on soils collected between canopies where soil NO^-_3-N was least, while seedling heights and biomass were greatest and foliage was dark green directly under the canopy where soil NO^-_3-N was greatest. The results show that instead of plowing and seeding creosotebush infested areas (as historically has been the case), a more effective approach would be to reduce creosotebush competition with a pelleted herbicide (tebuthiuron), wait for litter fall, then seed with a drill, thus allowing seedlings to utilize the increased water infiltration, reduced competition for soil moisture, as well as high amounts of soil NO^-_3-N located under the canopy. [RC]

Cox, J.R., and G.B. Ruyle. "Influence of climatic and edaphic factors on the distribution of *Eragrostis lehmanniana* Nees. in Arizona." *Journal of the Grassland Society of South Africa*. 3.1 (1986): 25-29.

[1986] Lehmann lovegrass was originally seeded on 69,115 hectares in the 1930's and has since spread by seed to an additional 76,040 hectares, and is the major plant species on roughly 145,000 hectares throughout the southwestern United States. Where Lehmann lovegrass dominates, surface soils are sandy, summer rainfall is greater than or equal to 200 mm, and winter temperatures rarely fall below 0°C. Five factors, both direct and indirect, have been found to significantly contribute to the spread of Lehmann lovegrass in southeastern Arizona.

Direct factors:

1) Mechanical soil disturbance and sowing: Following 1965, Arizona Department of Transportation began seeding disturbed soil along highway, pipeline and power-line construction. Spread of Lehmann lovegrass may be closely related to these seedings as they establish continuous corridors and traverse many environmental gradients.

2) Chemical brush control: Following chemical treatment of brush, Lehmann lovegrass is able to successfully replace native grasses.

Indirect factors:

3) Fire: Lehmann lovegrass populations are not adversely affected by fire, and it is quick to invade bare areas in native grass stands left after fire.
4) Cattle grazing: Selective grazing when Lehmann lovegrass and native grasses occur together may favor the establishment of Lehmann lovegrass.
5) Drought: When in shallow soils, Lehmann lovegrass is susceptible to drought, but seedlings quickly reoccupy sites when soil moisture conditions improve.

This study suggests that Lehmann lovegrass may be more narrowly adapted than previously thought and that its invasion into southeastern Arizona native rangelands has been ecologically curtailed. Any further population increase will largely be through increased stand densities or removal of shrub competition. [RC]

Cox, J.R., G.B. Ruyle, J.H. Fourie, and C. Donaldson. "Lehmann lovegrass – Central South Africa and Arizona, USA." *Rangelands*. 10.2 (1988): 53-55.

[1988] Lehmann lovegrass is widely distributed in west central South Africa, occurs at elevations between 2,800 and 4,800 feet, and occupies areas where annual rainfall varies between 8 and 22 inches. In Arizona, Lehmann lovegrass has invaded and become a major plant at elevations ranging from 3,250 to 4,800 feet and where the temperature rarely falls below 32°F for more than 4 hours within a 24-hour period. Surveys of areas in both South Africa and Arizona where Lehmann lovegrass has been dominant for more than 20 years show that both annual precipitation and mean max./min temperatures are similar, yet in South Africa 87% of the precipitation arrives in October and March, whereas in Arizona precipitation is bimodally distributed in summer (60%) and winter (40%). As cold temperatures are the primary regulator influencing spread, it is not expected Lehmann lovegrass will invade north, east, or southeast of its current distribution in the United States. [RC]

Cox, J.R., G.B. Ruyle, and B.A. Roundy. "Lehmann lovegrass in southeastern Arizona: biomass productions and disappearance." *Journal of Range Management*. 43.4 (1990): 367-372.

[1984-87] This study set out to determine annual fluctuations in live and dead Lehmann lovegrass biomass in wet and dry years so as determine potential productivity changes on Arizona rangelands after invasion, as well as how the presence of Lehmann lovegrass has affected animal utilization and grazing management. Live biomass peaked in August following wet, dry and normal summers. Lehmann lovegrass produces 3 to 4 times more forage than do native grasses, although cattle prefer native grasses. As such, the authors suggest using fencing to separate pure Lehmann lovegrass stands and native grass stands invaded by Lehmann lovegrass so as to force grazing, grazing Lehmann lovegrass in spring and summer, and resting native pastures in spring and summer followed by moderate grazing in fall and winter when grasses are inactive. [RC]

Cox, J.R., H.A. Schreiber, and H.L. Morton. "The initial growth of two range grasses on non-fertilized and fertilized soils collected from Creosotebush communities in the Southwestern United States." *Journal of Range Management*. 36.6 (1983): 726-729.

[1980-82] Soils were collected at three locations around creosote bush plants: the crown base, along the outer canopy, and in the areas between plants. The soils were then left alone or fertilized, and sown with Lehmann lovegrass and blue panicgrass (*Panicum antidotale* Ritz.) seed. Lehmann lovegrass plants grew small and stunted on unfertilized soil from the open areas and occasionally from the outer canopy. Leaf length and shoot production were greatest on fertilized soils from the crown base area. [RC]

Crider, F.J. "Three introduced lovegrasses for soil conservation." *USDA SCS Circular*. 730 (1945).

[1944] Lehmann lovegrass is a native grass of the Griqualand West region of South Africa, a predominantly dry area with hot summers, frosty winters, and erratic rainfall of 12 to 20 inches a year mostly (75-80%) in summer thunderstorms. The area has a low humidity and drought is not uncommon. Lehmann lovegrass is a perennial grass characterized by slender, smooth and flexible stems 18-36" long, short (6-8"), dark green leaves, and a branched, fibrous root system. It makes up part of the pioneering stages of grassland succession in its native habitat. Lehmann lovegrass seed was first acquired and brought to the United States for soil conservation purposes in 1932 by Dr. M. Wilman, then Director of the McGregor Museum in Kimberly, South Africa. After a series of test plantings, Lehmann lovegrass was found to possess a variety of qualities that made it ideal for soil conservation in the United States, namely its adaptability to a variety of soils, particularly poorer soils; quick establishment; rapidity of growth and maturity during critical periods; production of thick masses of vegetative soil cover; voluminous, tenacious, and deeply penetrating root system; resistance to destructive agencies; habits of self seeding; heavy yields of viable seeds; adaptation to simple methods of culture; and ease of eradication when circumstances warrant. The combination of these factors, the grass's relatively high food value to livestock, and America's wartime food production program led to mass production of accession Lehmann lovegrass A-68 seed at the Soil Conservation Service's Tucson nursery in 1935 and its distribution to other Soil Conservation Service centers, Bureau of Plant Industry field stations, and a number of state agricultural experiment stations. [RC]

Crimmins, T.M. and G.R. McPherson. "Vegetation and seedbank response to *Eragrostis lehmanniana* removal in semi-desert communities." *Weed Research*. 48 (2008): 542-551.

[2003-2004] To determine the vegetative community response to Lehmann lovegrass removal, it was removed from areas it was dominant using glyphosate at three locations in southeastern Arizona (Santa Rita Experimental Range (SRER), Montezuma Allotment (MA), and the Three Links Farm (TLF)). The seedbanks were sampled five times throughout the study period and viable seeds were characterized. At the two sites with histories of grazing (SRER and MO), Lehmann lovegrass removal was followed by significant increases in native cover and species richness. Throughout the course of the study period, progressively fewer Lehmann lovegrass seeds and higher numbers of native seeds were germinated from seedbank samples at SRER and MO. At TLF, which has a history of intense agricultural use and drier conditions, removal of Lehmann lovegrass was followed by an increase in aggressive non-native species as well as natives. The seedbank from TLF also showed native perennial grass seed in increasing quantities. [RC]

Cumming, K.J. "Lehmann lovegrass and simple time control grazing." *Rangelands*. 11.4 (1989): 150-153.

[1981-88] This paper aims to address two controversial issues in southeastern Arizona ranching; the use of Lehmann lovegrass to re-vegetate degraded ranges, and time control grazing. Both of these controversial methods were used to restore the graze-ability of a range in southeastern Arizona west of the Santa Cruz River. The study area was seeded with Lehmann lovegrass in 1949; three plots totaling 440 acres, of which 340 acres were Lehmann lovegrass, were used in a simple time control grazing system where each plot was heavily grazed for between five and ten days depending upon size, rate of growth of grass, observed utilization, and plant responses. It was found that Lehmann lovegrass is grazed more evenly under heavy grazing for a short period and the vigor and density of native perennials were not diminished in plots dense with Lehmann lovegrass. Sideoats grama increased during the study period. Lehmann lovegrass can be a valuable asset for ranchers as it often stays green in fall and spring when natives do not, it provides a high volume of forage, and its spread is limited to certain sites and does not displace desired native perennials. [RC]

Dennet, C.L., D. Clark, and A. Whalon. "Agave monitoring to determine effects of prescribed burn on this lesser long-nosed bat food source." In: Creative Cooperation in Resource Management, Third Conference on Research and Resource Management in the Southwestern Deserts, Extended Abstracts; 2000 May 16-18; Tuscon, AZ. Tuscon, AZ: USGS; 2000. P 23-24.

[1998-1999] Chiricahua National Monument in southeastern Arizona did prescribed burns in September 1998 and in November 1999. This study monitored the effects of these fires on Palmer agave, a plant of special importance as a food source for the endangered lesser long-nosed bat (*Leptonycteris curasoae yerbabuena*). Prior to the burn data was collected from ten 2 m transects in the burn areas including, among other things, presence and location of Lehmann lovegrass. Following the burns, which were low- to moderate-intensity burns through the grasslands, it was found that the presence of Lehmann lovegrass almost doubled the mortality of Palmer agave plants. The authors suggest this is because of altered fire behavior in Lehmann lovegrass stands including longer flames, faster rates of spread, and higher fireline intensity that is found in native grass fires. [RC]

Emmerich, W.E. and J.R. Cox. "Hydrology characteristics immediately after seasonal burning on introduced and native grasslands." *Journal Range Management*. 45.5 (1992): 476-479.

[1987-89] To determine if vegetation removal by fire is a dominant factor effecting surface runoff and erosion, surface runoff and sediment productions were evaluated immediately following vegetation removal by fall and spring burns at the Santa Rita Experimental Range (SRER) and the Empire-Cienega Resource Conservation Area in southeastern Arizona. The study site at the SRER consisted of an almost pure stand of Lehmann lovegrass on a White House gravelly loam soil. Neither of the two rainfall intensities produced a significant increase in runoff or sediment production at either site, indicating that vegetation cover alone is not the dominant factor controlling surface runoff and erosion. [RC]

Emmerich, W.E., and S.P. Hardegree. "Partial and full dehydration impact on germination of 4 warm-season grasses." *Journal of Range Management*. 49.4 (1996): 355-360.

[1995] To determine the effects on germination during the highly variable summer monsoon season, germination with short-term hydration and dehydration sequences was compared to constant water potential germination for sideoats grama (*Bouteloua curtipendula*), buffelgrass (*Cenchrus ciliaris*), kleingrass (*Panicum coloratum*) and Lehmann lovegrass. Seeds were imbibed at -0.2 MPa for 1 to 4 days then either air died or partially dehydrated at -0.3 MPa for 1 to 4 days, then returned to the imbibition solution for a total 14-day incubation-dehydration period. It was shown that Lehmann lovegrass germination was unaffected by dehydration treatments; it was the only species tested to have no response to dehydration. [RC]

Emmerich, W.E., and S.P. Hardegree. "Seed germination in polyethylene glycol solution: effects of filter paper exclusion and water vapor loss." *Crop Science*. 31 (1991): 454-458.

[1991] Study to examine the change in water potential caused by the polyethylene glycol (PEG) solution-saturated filter paper in petri dishes and vapor loss from unsealed containers. The influence of water potential change was tested in four grasses including Lehmann lovegrass. Lehmann lovegrass was the only species that did not exhibit a measurable effect in either total germination or germination rate. The authors suggest that this is likely due to low germination at lower water potentials, and the chance that ethylene –being created in the vials between daily water additions – stimulated germination. [RC]

English, N.B., J.F. Weltzin, A. Fravolini, L. Thomas, and D.G. Williams. "The influence of soil texture and vegetation on soil moisture under rainout shelters in a semi-desert grassland." *Journal of Arid Environments*. 63.1 (2005): 324-343.

[2002] Study to determine how changes in summer precipitation and invasion by Lehmann lovegrass interacts with soil texture to affect ecosystem and community processes in temperate grassland ecosystems of southern Arizona. This was accomplished through the use of six 9m x 18m rainout shelters on seventy-two 2.7m^2 plots and the measurement of soil moisture at several soil depths. Transects were located on both a clay-rich soil and a sand-rich soil. In both soils, vegetated plots lose water faster than bare soil, most likely due to transpiration by grasses. On the sand-rich soils, water loss was equal among plots of Lehmann lovegrass and native tanglehead (*Heteropogon contortus*) on the sand-rich soil, while on the clay-rich soil, water loss was greater on the Lehmann lovegrass plots. [RC]

Fernandez, R.J., and J.F. Reynolds. "Potential growth and drought tolerance of eight desert grasses: lack of a trade-off?" *Oecologia* 123 (2000): 90-98.

[1999] To test the hypothesis that there is an inverse relationship between relative growth rates under well-watered conditions and the capacity to tolerate drought, the physiological (gas exchange) and morphological (biomass allocation, leaf properties) determinants of growth were tested under three water conditions (none=control, moderate drought, severe drought) for eight C-4 perennial grasses including Lehmann lovegrass. All grasses aside from Lehmann lovegrass were native to the Chihuahuan Desert. Final biomass of all grasses was reduced with drought, with above ground biomass being more affected than below. Specific leaf area and photosynthetic rate per unit of leaf was decreased with drought, while stomatal conductance and water use efficiency were not affected by drought. Of the eight species tested, Lehmann lovegrass alone was found to produce an increasingly greater proportion of reproductive tillers as drought became more severe. [RC]

Fernandez-Giminez, M.E. and Smith, S.E. "Research observations: nitrogen effects on Arizona cotton-top and Lehmann lovegrass seedlings." *Journal of Range Management*. 57.1 (2004): 76-81

[2000] To determine if Lehmann lovegrass displayed greater growth or nitrogen use efficiency than native Arizona cottontop (*Digitaria californica*), seedling responses to 7 nitrogen and 2 water treatments were compared over the course of 8 weeks. After 8 weeks, Lehmann lovegrass had greater nitrogen concentrations and lower C:N ratios, while Arizona cottontop produced greater biomass per plant, exhibited greater nitrogen use efficiency, and tolerated high nitrogen levels better. These results suggest that while Arizona cottontop may be a superior nitrogen competitor under limited and high nitrogen levels, Lehmann lovegrass may be more competitive at more moderate nitrogen levels. [RC]

Flanders, A.A., W.P. Kuvlesky, Kr., D.C. Ruthven III, R.E. Zaiglin, R.L. Bingham, T.E. Fulbright, F. Hernandez, and L.A. Brennan. "Effects of invasive exotic grasses on south Texas rangeland breeding birds." *The Auk*. 123.1 (2006): 171-182.

[2001-2002] In light of the simplification of native plant community composition following invasion by exotic species, this study examined the effects of Lehmann lovegrass and buffelgrass (*Cenchrus ciliaris*) on grassland bird abundance and species richness, native flora, and arthropods in south Texas. Native grass cover was >400% greater on native grass sites than on exotic grass sites, forb and grass species richness was higher on native sites, although shrub canopy cover, bare ground and vegetation height were similar for native and exotic sites. Bird abundance was higher on the native grass plots with lark sparrow (*Chondestes grammacus*) 73% more abundant on native sites and back-throated sparrow (*Amphispiza bilineata*), northern Mockingbird (*Mimus polyglottos*), northern bobwhite (*Colinus virginianus*), and Cassin's sparrow (*Aimophilla cassini*) 26-70% more abundant on native sites. Birds that foraged under open brush canopies were almost twice as abundant on native sites than on exotic sites, likely due to less abundant sources of seed and insect resources available. Native sites had 60% greater abundance of arthropods than exotic sites with spiders, beetles, and ants 42-83% more abundant on native sites. Although habitat structure was similar among native and exotic sites, differences in floristics may affect bird preference resulting in lower abundance in grasslands dominated by exotic grasses. Exotic dominated sites also may not provide niches for stenotopic or monophagous invertebrates that serve as food sources for birds, thus making exotic dominated sites less desirable. [RC]

Foy, C.D., A.J. Oakes, and J.W. Schwartz. "Adaptation of some introduced *Eragrostis* species to calcareous soil and acid mine spoil." *Communications in Soil Science and Plant Analysis*. 10.6 (1979): 953-968.

[1978] In the search for plant species that can grow in strongly acidic soils and acid mine spoils, 20 accessions of 4 species of *Eragrostis* spp. were grown in a 50:50 mixture of Quinlan and calcareous Millville soils (pH 7.3). 10 accessions of Lehmann lovegrass were tested in the study. Two accessions of Lehmann lovegrass (937 and 942) were tolerant of the calcareous soil. 30 days after seeding both these Lehmann lovegrass accessions were green, 55 days after seeding accession 942 was chlorotic (lacking green coloration of leaves) while 937 remained green. The chlorotic accession 942 contained higher concentrations of iron and phosphorous and lower concentrations of manganese than the green 937. Dry weight of top yield cuttings at 55 days were 3.6 grams per pot for accession 937 and 1.68 grams per pot for accession 942. [RC]

Frasier, G.W. and J.R. Cox. "Water balance in a pure stand of Lehmann's lovegrass." *Journal of Range Management*. 47.5 (1994): 373-378.

[1984-85] In a three-year study examining the water balance in stands dominated by Lehmann lovegrass, it was found that this South African exotic can extract more water from the soil than occurred as precipitation. During the test period, which had below average precipitation, total amount of water stored in the soil declined while a significant amount of water was removed from the soil by plant growth or evaporation during the winter, and much of the remaining water was exhausted in the spring dry period. It appears Lehmann lovegrass has a threshold water level for growth; any water above this threshold does not result in greater biomass production, but instead passes directly through the plant without contributing to growth or is lost through evaporation from the soil. The authors hypothesize that Lehmann lovegrass can utilize soil water at times of the year when native grasses are dormant, utilize relatively deep water, and extract water from soil when water content is very low. [RC]

Frasier, G.W., J.R. Cox, and D.A. Woolhiser. "Emergence and survival responses of seven grasses for six wet-dry sequences." *Journal of Range Management*. 38.4 (1985): 372-377.

[1984] A study to determine the seedling emergence and survival responses of 7 warm-season grasses to 6 combinations of initial wet-day and dry-day sequences included both Lehmann lovegrass as well as the cultivar Cochise lovegrass (*Eragrostis lehmanniana* X *E. trichophora*). Lehmann lovegrass did not have significant seedling emergence until there were 3 or more wet days in a row and its initial seedlings were robust enough to withstand the subsequent dry period. Furthermore, its seed remained viable in the soil even during dry periods. Cochise lovegrass emerged after 2 wet days, but had a high mortality during the first dry period. While quick seed germination may seem an effective establishment strategy at first glance, unless the seedlings produced are vigorous enough to survive the dry period or the soil contains viable seed all is for naught. [RC]

Frasier, G.W., J.R. Cox, and D.A. Woolhiser. "Wet-dry cycle effects on warm-season grass seedling establishment." *Journal of Range Management*. 40.1 (1987): 2-6.

[1983] In a study to evaluate seedling establishment characteristics of various warm-season grasses (including Lehmann lovegrass), a series of 14-day field experiments were conducted involving controlled wet-dry watering combinations at the Walnut Gulch Experimental Watershed near Tombstone, Arizona. When the wet periods were 2 days long, Lehmann lovegrass seeds generally didn't germinate but were viable following subsequent dry periods. Seedlings were produced with 5-day wet periods that were able to survive drought periods of 5- to 7-days. A 3-days wet period produced less seedlings than either 2- or 5-days wet period. For both field and greenhouse trials, seedlings became established when relative humidity exceeded 50% for over one-half of the time during the initial wet-dry period. [RC]

Frederickson, E.L., R.E. Estell, K.M. Havstad, T. Ksiksi, J. van Tol, and M.D. Remmenga. "Effects of ruminant digestion on germination of Lehmann love-grass seed." *Journal of Range Management*. 50.1 (1997): 20-26

[1995] To determine the potential of sheep as dispersal agents of Lehmann lovegrass, seeds were subjected to four different ruminant treatments. Treatment 1 tested viability of Lehmann lovegrass seeds exposed to ruminal and postruminal digestion; treatment 2 tested the influence of ruminal microbial digestion on seed degradation and viability; treatment 3 tested the effects of mastication on viability of seed; treatment 4 compared *in vitro* techniques and *in sacco* techniques used to estimate the effect of digestion on seed viability. Viable seed was recovered in each of the treatments. The results of the study show that Lehmann lovegrass seed can pass through the ruminant digestive tract and thus ruminants are potential disseminating agents of Lehmann lovegrass. [RC]

Freeman, D. "Lehmann lovegrass." *Rangelands*. 1.4 (1979): 162-163.

[1939-79] In summer of 1939, Louis Hamilton from the Tucson Nursery gave 10 pounds of Lehmann lovegrass seed to the author and asked that it to be sown in the field as it had never been grown outside. The author sowed the seed on 100 acres in southeastern Arizona (Pearce, Cochise County). The following year the author seeded Lehmann lovegrass on the Babacomari, the Charlie Miller, and the Bill Stevenson ranches in southeastern Arizona. Upon seeing the spread of Lehmann lovegrass years later and livestock's use of it, the author remarks "all will agree, I'm sure, that the first 10-pound, 100-acre field trial seedling of Lehmann lovegrass started a highly successful venture in many ways for the warm arid lands of the southwestern United States..." [RC]

Geiger, E.L. and G.R. McPherson. "Response of semi-desert grasslands invaded by non-native grasses to altered disturbance regimes." *Journal of Biogeography.* 32.5 (2005): 895-902.

[1987-2002] Studied the response of Lehmann lovegrass, velvet mesquite, and native plant species to the reintroduction of fire and the removal of livestock from Buenos Aires National Wildlife Refuge in southern Arizona. Although prior research has suggested that the germination and establishment of Lehmann lovegrass is enhanced by fire, this study found it had neither a positive or negative influence on Lehmann lovegrass. Transects with low clay contents had increased cover of Lehmann lovegrass, and Lehmann lovegrass was common on uplands with deep sandy loams, and rare on clay loams and shallow uplands with sandy loam. This study shows that the variability of richness, diversity, and cover over time seem to be linked to fluctuations in precipitation rather than human-altered disturbance regimes. Furthermore, effects of altered disturbance regimes are likely to be confounded by interactions with climatic factors in systems significantly altered from their original physiognomy. [RC]

Gottesman, A.B., P.R. Krausman, M.L. Morrison, and Y. Petryszyn. "Movements and home range of brush mice." *The Southwestern Naturalist*. 49.2 (2004):289-294.

[2000-2001] This study set out to examine the home range and breadth of movement of brush mice (*Peromyscus boylii*) in southeastern Arizona in light of their role as primary carriers of Sin Nobre virus, the etiologic agent for the disease hantavirus pulmonary syndrome in humans. The home range and movements of radio collared brush mice were examined on the Santa Rita Experimental Range. It was found that the home range of brush mice is dominated by mesquite (*Prosopis*), cactus (*Opuntia*), acacia (*Acacia*), mimosa (*Mimosa*), false mesquite (*Caliiandra*), three-awns (*Aristida glabrata*), gramas (*Bouteloua*), and Lehmann lovegrass. [RC]

Haferkamp, M.R, and G.L. Jordan. "The effect of selected presowing seed treatments on germination of Lehmann lovegrass seeds." *Journal of Range Management*. 30.2 (1977): 151-153.

[1976] Lehmann lovegrass seeds were subjected to one of numerous treatments including oven drying (24 hours at 70°C), scarification (8 seconds in a modified Forsberg seed cleaner), warm vapor imbibition for 24, 48, and 72 hours at 24°C (with half followed by oven drying for 24 hours at 70°C), and cold water imbibition for 24, 48, and 72 hours at 10°C (with half followed by oven drying for 24 hours at 70°C). Pretreating Lehmann lovegrass seeds with treatments of mechanical scarification, oven drying, or moistening plus oven drying allowed rapid germination to occur. Conditions similar to moistening plus oven drying might occur in a natural field setting. [RC]

Hardegree, S.P., and W.E. Emmerich. "Germination response of hand-threshed Lehmann lovegrass seeds." *Journal of Range Management*. 46.3 (1993): 203-207.

[1991] Both seed after-ripening and seed scarification were found to increase germination of Lehmann lovegrass in this study. Lehmann lovegrass seeds from 5 sites throughout Arizona (Chiricahua, Sonoita, Gleeson, Continental, and Sasabe) were germinated over a water potential range of 0 to -1.55 MPa and evaluated at 3, 7, 11, 18, 34, 46, and 88 weeks. Non-scarified and hand-threshed seeds averaged less than 9% germination 88 weeks after harvest, while seeds scarified before after-ripening showed higher germination 46 weeks after harvest. After-ripening was an important factor only in the first nine months following harvest. Non-scarified seeds had so little germination that a comparison of scarification effects on germination could not be made. [RC]

Hardegree, S.P., and W.E. Emmerich. "Variability in germination rate among seed lots of Lehmann lovegrass." *Journal of Range Management*. 44.4 (1991): 323-326.

[1990] To determine if differences in the degree of mechanical scarification during harvest, threshing, and storage in some part cause the variability in germination rates of scarified and non-scarified Lehmann lovegrass seeds from 7 different seed lots were germinated over the water potential range of 0-1.16 MPa. It was found that mechanical scarification increased total germination as well as germination rates. While mechanical scarification reduced variability among seed lots for germination, it also increased variability for total germination. High levels of variability between seed lots calls into question the validity of prior studies comparing germination of single seed lots of Lehmann lovegrass to that of other species. [RC]

Heske, E.J., J.H. Brown, and Q.F. Guo. "Effects of kangaroo rat exclusion on vegetation structure and plant-species diversity in the Chihuahuan desert." *Oecologia*. 95.4 (1993): 520-524.

[1977-1990] On plots in the Chihuahuan desert, three species of kangaroo rats were excluded from 1977 until 1990. The exclusion had dramatic effects on the structure and composition of vegetation and resulted in significant increases of both Lehmann lovegrass as well as sixweeks threeawn (*Aristida adscensionis*), which in turn lead to an increased use of these plots by grass-living rodents and a decrease in use by seed-foraging birds. The mechanisms producing these effects are not entirely understood. As sixweeks threeawn is a food item of the kangaroo rats, the absence of seed predation may lead to an increase in sixweeks threeawn, while Lehmann lovegrass may increase due to the lack of soil disturbance when kangaroo rats are removed. After 12 years of kangaroo rat exclusion, there was no loss in diversity recorded. [RC]

Huang, C. and E.L. Geiger. "Biodiversity Research: Climate anomalies provide opportunities for large-scale mapping of non-native plant abundance in desert grasslands." *Diversity and Distributions*. 14.5 (2008): 875-884.

[2000] Climate anomalies may allow for the detection of non-native species at a regional scale using remote sensing. Based on this mechanism, the authors examined the relationship between remotely sensed greenness (delta Enhanced Vegetation Index (ΔEVI) from the Moderate Resolution Imaging Spectroradiometer (MODIS)) and actual and percentage biomass of Lehman lovegrass. The study took place on Fort Huachuca Military Reservation in southern Arizona during an abnormally wet, cool period in October. Although the phenology of native grass communities and Lehmann lovegrass are similar, Lehmann lovegrass produces a significant amount of new tissue and seed following cool season moisture while natives tend to remain in senescence or dormancy. Because of this, an increase in ΔEVI during wet, cool seasons would indicate an abundance of Lehmann lovegrass, which was verified using field actual and percentage biomass values. This method allows for a direct and cost-efficient means of mapping Lehmann lovegrass invasion on a regional scale. [RC]

Huang, C., E.L. Geiger, W.J.D. Van Leeuwen, and S.E. Marsh. "Discrimination of invaded and native species sites in semi-desert grassland using MODIS multi-temporal." *International Journal of Remote Sensing*. 30.4 (2009): 897-917.

[1988-2005] Through the use of time-series field observations, Moderate Resolution Imaging Spectroradiometer Normalized Difference Vegetation Index (MODIS NDVI), and red and near-infrared reflectance data, this study set out to characterize the phenology of systems occupied by Lehmann lovegrass and/or native grasses. It was shown that both phenological and ecophysiological characteristics of native, mixed, and Lehmann lovegrass-dominated communities can be delineated using MODIS NDVI and red and near-infrared reflectance data. The study showed that Lehmann lovegrass sites do not produce as much greenness as native sites at any time of the year owing to annual grass and herbaceous dicots in native sites. The large amount of standing litter and bright-colored biomass associated with Lehmann lovegrass may inhibit green signals and cause low NDVI predictability to herbaceous biomass. Native sites that included annual and perennial grasses, herbaceous dicots, and small shrubs with different growing periods (meaning greater consistency in amount of greenness) had lower temporal variation of NDVI than that of the Lehmann lovegrass dominated sites. Sites infested with Lehmann lovegrass had lower temporal-spatial NDVI and red reflectance variation owing to the fact that it forms a homogenous landscape that is a dense uni-tonal layer of green grass or yellow litter. Theses techniques can be used to monitor the spread of Lehmann lovegrass more regularly than has been done in the past. [RC]

Hull, H.M., F.W. Went, and C.A. Bleckmann. "Environmental modification of epicuticular wax structure of Prosopis leaves." *Journal of the Arizona-Nevada Academy of Science*. 14.2 (1979): 39-42.

[1979] In a study to examine a variety of influences on the chemistry of surface waxes on two mesquite (*Prosopis*) species, it is noted incidentally that in recent ultrastructural investigations of experimental lines of Lehmann lovegrass, a distinct positive correlation has been made between drought tolerance and the frequency of large wax plates on the leaves. [RC]

Humphrey, R.R., and A.C. Everson. "Effects of fire on a mixed grass-shrub range in southern Arizona." *Journal of Range Management*. 4.4 (1951): 264-266.

[1949-1959] A study conducted on the Page-Trowbridge Experimental Ranch in southeast Arizona examined the effects of a pre-monsoon fire on an area with Lehmann lovegrass and six shrubs/half-shrubs (burroweed, snakeweed, jumping cholla, cane cholla, prickly pear, and velvet mesquite). The burn reduced the stand of Lehmann lovegrass by about one third and killed few plants, but one year later the stand was growing vigorously with nodal propagation and a good crop of seed. All of the shrubs aside from velvet mesquite decreased following the fire. [RC]

Hupy, C.M., Whitford, W.G., and E.C. Jackson. "The effect of dominance by an alien species, Lehmann lovegrass, *Eragrostis lehmanniana*, on fauna lpedoturbation patterns in North American Desert grasslands." *Journal of Arid Environments*. 58 (2004): 321-334.

[2003] In a study of the effects of Lehmann lovegrass dominance on semi-arid grassland ecosystems, the soil disturbance caused by animals in areas dominated by Lehmann lovegrass was compared to areas dominated by native plants. Experimental plots were set up at the Santa Rita Experimental Range (SRER) in southeastern Arizona and the Jornada del Muerto basin in New Mexico. Evidence shows that time since establishment was important in determining effects. At SRER, where Lehmann lovegrass was seeded in 1937, soil disturbance by ground squirrels and Attine (fungus growing) ants was sparse or absent. There were many variations among, within, and between the study areas, which was attributable to site history, faunal differences, and geographic and topographic positions. The absence of some important animals, i.e. pocket gophers, in Lehmann lovegrass dominated areas may lead to changes in soil texture. In turn, this may lead to reduced cover and/or abundance or loss of native plant species. [RC]

Huxman, T.E., J.M. Cable, D.D. Ignace, A.J. Elits, N. English, J.F. Weltzin, and D.G. Williams. "Response of net ecosystem gas exchange to a simulated precipitation pulse in a semi-arid grassland: the role of native versus non-native grasses and soil texture." *Oecologia*. 141 (2004): 295-305.

[2003] Explored the short-term dynamics of ecosystems physiology in stands of native Tanglehead grass and Lehmann lovegrass to irrigation pulses across two surfaces with different soils: a Pleistocene-aged soil (high clay content, strongly horizontated) and a Holocene-aged soil (low clay content, homogenously structured). Before an irrigation pulse was applied, both the native grass and the Lehmann lovegrass exhibited less pre-dawn water potentials, and greater leaf photosynthetic rates, stomatal conductance, and rates of net ecosystem carbon exchange (NEE) on the Pleistocene-aged soil. 24 hours after the application of the 39 mm irrigation pulse soil CO_2 efflux increased leading to a loss of CO_2 in all plots. Although maximum NEE increased for both species and soils at approximately the same rate, the Lehmann lovegrass stands had greater rates of evapotranspiration (ET) immediately following the pulse. The ET patterns were correlated to an earlier decline in NEE in the invasive species plots as compared to the native species plots. The invasive species plots accumulated between 5% and 33% of the carbon that the native species plots did over the 15-day pulse period. [RC]

Ignace, D.D., T.E. Huxman, J.F. Weltzin, and D.G. Williams. "Leaf gas exchange and water status response of a native and non-native grass to precipitation across contrasting soil surfaces in the Sonoran Desert." *Oecologia*. 152.3 (2007): 410-413.

[2001] A study to determine how soil surface and seasonal timing of rainfall mediate the dynamics of leaf-level photosynthesis and plant water status of both a native grass, tanglehead (*Heteropogon contortus*) and a non-native grass (Lehmann lovegrass) in response to a precipitation event. It was found that soil surface (either sandy or clay-rich) did not always amplify differences in plant response. June precipitation (mimicking precipitation at prior to the onset of the monsoon) lead to increases in plant water status and photosynthesis, while August precipitation (mimicking the peak of the monsoon) did not. This was due to favorable soil moisture condition that facilitated high plant performance. It was shown that Lehmann lovegrass did not demonstrate higher photosynthetic performance than the native grass in either of the soil types. [RC]

Jones, Z.F., and C.E. Bock. "The Botteri's sparrow and exotic grasslands: an ecological trap or habitat regained?" *The Condor*. 107.4 (2005): 731-741.

[1999-2001] Extirpated in Arizona in the late 19th century, Botteri's sparrow arrived in Arizona again in 1967 and became locally common in stands of sacaton (*Sporobolus wrightii*). By the 1980's, Botteri's had become locally abundant in areas dominated by Lehmann lovegrass. The objective of the study was to determine if the bird's habitat preferences also reflected higher reproduction rates, and whether Lehmann lovegrass dominated grasslands are an ecological trap or an ecological opportunity for Botteri's sparrows. It was found that abundance of Botteri's sparrow was intermediate in Lehmann lovegrass stands, lowest in native upland grasslands, and highest in sacaton stands. It was also found that Lehmann lovegrass, far from being an ecological trap, is providing Botteri's sparrow with an ecological opportunity and perhaps even facilitating the return to regional abundance seen before the overgrazing and droughts of the late 19th century. Given the general negative impacts of exotic and invasive species on local biodiversity however, restoration of native ecosystems should rank far ahead of utilization of invasive species as conservation tools. [RC]

Jones, Z.F., C.E. Bock, and J.H. Bock. "Rodent communities in a grazed and ungrazed Arizona grassland, and a model of habitat relationships among rodents in southwestern grass/shrublands." *American Midland Naturalist*. 149.2 (2003): 384-394.

[1981-83, 2000-01] Rodents were live-trapped in 2000-2001 at eight sites on ungrazed grassland and on adjacent grazed cattle ranches in the Sonoita valley in southeastern Arizona. One of the eight sites had been previously trapped in 1981-1983. It was found that the species Muridae were more common on ungrazed plots, while no species was more abundant on grazed plots. The species Muridae (specifically *Sigmodon*, *Baimys*, and *Reithrondontomys*) were found to dominate areas the most and fullest ground cover, and pocket mice (*Chaetodipus* and *Perognathus*) were common in areas of intermediate cover. The ungrazed sites exhibited an increase in vegetative height and grass canopy between 1981-83 and 2000-01 due substantially to invasion by Lehmann lovegrass, which favors Muridae species. The results of this study indicate that a mosaic landscape of grass and shrublands with varying amount of ground cover will likely maintain the highest regional diversity of rodents. [RC]

Kuvlesky, W.P., Jr., T.E. Fulbright, and R. Engel-Wilson. "The impact of invasive exotic grasses on quail in the southwestern United States." In: S.J. DeMaso, W.P. Kuvlesky, Jr., F. Hernandez, and M.E. Berger, editors. *Quail V.* The Fifth National Quail Symposium; 2002.Texas Parks and Wildlife Department, Austin, TX. 2002. 118-128.

[2001] The habitat of five native quail (bobwhite (*Colinus virginianus*), scaled (*Callipepla squamata*), Gambel's (*C. gambellii*), Montezuma (*Cytronyx montezumae*), and California (*C. californicus*)) in arid and semi-arid ecosystems in the southwest United States were studied to determine the impacts of invasive grasses on these species.

Research has shown than bobwhites inhabiting the Buenos Aires National Wildlife Refuge (BANWR) are equally as likely to be found in stands of Lehmann lovegrass as in native stands. Lehmann lovegrass may serve as important herbaceous cover for bobwhites when native cover is limited, although native stands most likely offer more food advantages and cover advantages. Scaled quail on BANWR preferred to inhabit upland habitats, the dominant herbaceous species being Lehmann lovegrass, though it has been reported that scaled quail were less abundant in stands of Lehmann lovegrass and preferred areas with low perennial grass cover. It has been suggested that scaled quail will tolerate exotic grass areas if sufficient forb and insect populations are present. Similarly, it appears that Gambel's quail will tolerate areas dominated by exotic grasses only if sufficient forbs and insects are provided. There is not adequate research on Montezuma quail to determine any reactions to exotic grasses. All species of quail are experiencing population reductions and while habitat loss has largely been blamed, habitat loss due to invasive species has been overlooked. Research shows that if native habitat is not available most quail will tolerate invaded areas so long as sufficient forbs and insects are available, but exotic grass invasions generally reduce herbaceous structural diversity and hence reduce forb and insect diversity. [RC]

Mantlana, K.B. E.M. Veenendaal, A. Arneth, V. Grispen, C.M. Bonyongo, I.G. Heitkonig, and J. Lloyd. "Biomass and leaf-level gas exchange characteristics of three African savanna C-4 grass species under optimum growth conditions." *African Journal of Ecology*. 47.4 (2009): 482-489.

[2009] So as to characterize the above- and below-ground biomass allocation and gas exchange response of to changes in light intensity CO_2 concentration, and leaf-to-air vapor pressure deficit gradient, three C_4 savanna grass species (Lehmann lovegrass, pangola grass, and torpedo grass) were grown under optimum growth conditions. Lehmann lovegrass had roughly half the dry weight biomass as the other two species, a significantly lower ratio of leaf to total plant weight, and a root length per unit root biomass lower than pangola grass but equal to torpedo grass. Lehmann lovegrass exhibited the lowest carboxylation efficiency, the lowest CO_2 compensation point, and the lowest leaf-to-air vapor pressure deficit. It had the highest light saturated net photosynthetic rate and light and CO_2 saturated net photosynthetic rate, and the lowest saturating light water use efficiency, but the lowest ambient water use efficiency. [RC]

Martin, M.H., and J.R. Cox. "Germination profiles of introduced lovegrasses at six constant temperatures." *Journal of Range Management*. 37.6 (1984): 507-509.

[1983] Seeds from four *Eragrostis spp.* accessions including Lehmann lovegrass and Cochise lovegrass (*Eragrostis lehmanniana* X *E. trichophorpha*) were germinated for 14 days at constant temperatures of 15, 18, 21, 24, 27, and 30°C with a 15-hour photoperiod. Germination of Cochise seeds was optimum with a temperature between 21 and 27°C after 12 days, while Lehmann lovegrass germination was optimum at 27°C after 12 days. The results show that Cochise lovegrass will germinate at relatively low temperatures while Lehmann lovegrass requires higher temperatures for germination. These results may help to explain why Lehmann lovegrass has persisted in the Sonoran Desert where spring-fall precipitation events are more likely to occur than in the Chihuahuan Desert. [RC]

Martin, S.C., and H.L. Morton. "Mesquite control increases grass density and reduces soil loss in southern Arizona." *Journal of Range Management*. 46.2 (1993): 170-175.

[1974-1986] Of 8 pairs of gully headcuts on the Santa Rita Experimental Range (SRER), the authors killed one mesquite (*Prosopis velutina*) per pair with diesel oil to determine the effects of mesquite on densities of shrubs and perennial grasses, shrub cover, surface erosion, headcut advance, and gully depth. These factors were recorded at 3-year intervals for 12 years. Four pairs were in pastures grazed yearlong, while four were in Santa Rita rotations (grazed once March-October and once November-February in 3-year rotation with 12 month rest between grazing periods). Of each set of four headcuts, two were about 200 m higher in elevation that the other two. Perennial grass densities increased from 1974-77, peaked in 1983 and had declined by 1986. Perennial grass density was greater where mesquite had been killed and at higher elevations. Lehmann lovegrass increased significantly on the higher elevation headcuts where mesquite had been killed, replacing Arizona cottontop, Santa Rita threeawns, other threeawns, and plains bristlegrass (all of which increased at the lower elevation headcuts where mesquite had been killed sans Lehmann lovegrass). [RC]

Martin, S.C., and H.L. Morton. "Responses of falsemesquite, native grasses and forbs, and Lehmann lovegrass after spraying with picloram." *Journal of Range Management*. 33.2 (1980): 104-106.

[1972-1977] To determine the responses of perennial grasses following treatment by picloram herbicide to control falsemesquite (*Calliandra eriophylla*), aqueous sprays of picloram at the rate of 0.56 kg/ha were applied to five plots on the Santa Rita Experimental Range in May 1963 and August 1976. While falsemesquite, perennial forbs, and native perennial grasses were greatly reduced on both treated and untreated plots, the greatest vegetation change on sprayed and unsprayed plots alike was the significant increase in density and yield of Lehmann lovegrass (from 10-27% in 1973 to 77-88% in 1977). [RC]

Mau-Crimmins, T.M., H.R. Schussman, and E.L. Geiger. "Can the invaded range of a species be predicted sufficiently using only native-range data? Lehmann lovegrass (*Eragrostis lehmanniana*) in the southwestern United States." *Ecological Modelling*. 193 (2006): 736-746.

[2005] To enable the early detection of invasive species and predict areas most likely to be invaded, this study aimed to determine whether environmental data (elevation, slope, aspect, flow direction, flow accumulation, and topographic index) from an invader's native range or invaded range is useful and/or accurate in determining potential spread using the case of Lehmann lovegrass spread in southeastern Arizona as a proxy. The study showed that information gathered from an invaded range may be rather useful in providing information regarding potential spread. Invaded range information can provide insight into environmental conditions tolerated by the invader as well as inconsistencies between native and invaded ranges caused by intense selection, asexual reproduction, and limited introduction numbers. This method may be most useful for invasive species that are purposefully introduced and have been intensely selected, such as Lehmann lovegrass. [RC]

McCLaran, M.O. and M.E. Anable. "Spread of introduced Lehmann lovegrass along a grazing intensity gradient." *Journal of Applied Ecology*. 29 (1992): 92-98.

[1978-91] Change in Lehmann lovegrass and native grass density as well as percent Lehmann lovegrass density along a livestock grazing gradient was measured on six permanent plots (1972-1990) at the Santa Rita Experimental Range in Arizona. Lehmann lovegrass density increased but was not affected by different grazing intensities, while native densities decreased and percent Lehmann lovegrass increased both over time and as grazing intensity increased. Density did not differ between un-grazed exclosures and comparable grazed areas. Although grazing was not necessary for Lehmann lovegrass to spread, it did make up a greater proportion of the total grass population at higher grazing densities. [RC]

McClaran, M.P., W.W. Brady. "Arizona's diverse vegetation and contributions to plant ecology." *Rangelands*. 16.5 (1994): 208-217.

[1993] The state of Arizona covers more than 70 million acres, lays between 31° and 36° latitude, is 80% state or federal land, and it's climate is generally arid with a bimodal precipitation pattern of wet summers and moderately moist winters. The state is home to over 3,4000 vascular taxa and hosts nine distinct plant communities including desert scrub, desert grassland, chaparral, northern desert scrub, juniper-pinyon woodland, oak woodland, ponderosa pine forest, mixed conifer forest, and riparian forest. The desert grassland community covers nearly 15 million acres in southeastern and central Arizona, and herbaceous, shrubby, and short tree species with at least 20-40% bare ground. Conspicuous species include velvet mesquite (*Prosopis velutina*), burroweed (*Isocoma tenuisecta*), snakeweed (*Gutierrezia sarothrae*), Arizona cottontop (*Digitaria californica*), tobosa (*Hilaria mutica*), gramas (*Bouteloua* spp.). In the last 11,000 years, the dominant woody species have changed from pine, juniper, and oak to the more subtropical velvet mesquite and desert hackberry (*Celtis pallida*) while the dominant grass species have remained the same. In the past 100 years, the abundance of woody species (esp. velvet mesquite) has increased while native grass has decreased. The introduction and spread of Lehmann lovegrass represents a vegetation change of similar magnitude to the contemporary increase of woody species and the disappearance of pines, junipers and oaks over the last 11,000 years. [RC]

McDonald, C.J. "Appendix A: Survival of Lehmann lovegrass and native grasses after fire: promoting the absence of a grass/fire cycle through proverb." *Management of nonnative perennial grasses in southern Arizona: effects of prescribed fire and livestock grazing*. Ph.D. dissertation, University of Arizona, 2009.

[2005-2008] In light of contradictory literature regarding fire regime and establishment of Lehmann lovegrass, this study aimed to determine the effects of fire on the survival of individual grasses on plots dominated by Lehmann lovegrass, native grasses or a mixture of the two. 54 plots comprising 1500 individual grasses were studied on the Santa Rita Experimental Range. Some of the plots were burned while others were left unburned throughout the 2-year study period. Native grasses had higher survival rates on both burned and unburned plots, sometimes nearly double that of Lehmann lovegrass. The percent of established Lehmann lovegrass plants on the study plots had not increased two years after the burns. The results of this study suggest that a grass/fire cycle that includes Lehmann lovegrass may be absent from southern Arizona, and that fire can be a useful tool for rehabilitation and restoration of degraded grasslands. [RC]

McDonald, C.J. "Appendix B: The grass/fire cycle in a semi-arid grassland: response of an invasive grass and native plants to fire and grazing suggest the absence of a positive feedback cycle." *Management of nonnative perennial grasses in southern Arizona: effects of prescribed fire and livestock grazing*. Ph.D. dissertation, University of Arizona, 2009.

[2005-2008] Study set out to determine the effects of prescribed burns and livestock grazing on grassland plant communities dominated by Lehmann lovegrass. Of 24 plots established on the Santa Rita Experimental Range, half were burned, grazed, burned and grazed, or left alone in 2005, while the other half received similar treatments in 2006. It was found that prescribed fire reduced Lehmann lovegrass abundance 1-2 years after the burn, while abundance of native grasses, herbaceous dicots, and fall plant richness and diversity increased. Both livestock grazing and combination grazing/burn negatively affected native grass as livestock preferentially graze native grasses, and may enhance the dominance and spread of Lehmann lovegrass. The results of this study show that fire does not promote the spread of Lehmann lovegrass as previously thought, and that human alteration of fire regimes in semi-arid grasslands are greater than those of Lehmann lovegrass introduction. [RC]

McGlone, C.M., and L.F. Huenneke. "The impact of a prescribed burn on introduced Lehmann lovegrass versus native vegetation in the Northern Chihuahuan desert." *Journal of Arid Environments*. 57 (2004): 297-310.

[1998-2000] Because of the high shrub-seedling mortality rate following burning, prescribed burning has been proffered as a means of preventing shrub encroachment on arid rangelands. So as to determine the effects of prescribed burns on Lehmann lovegrass in the Chihuahuan desert, the authors established 12 transects on the Jornada Experimental Range outside of Las Cruces, NM prior to a three day prescribed burn that burned ~95% of the vegetative cover. Transects were placed inside areas infested with Lehmann lovegrass and areas not invaded. Prior to burning, canopy cover of the Lehmann lovegrass areas was nearly twice that of the native areas, as a result the Lehmann lovegrass patches carried the fire quicker and with fewer ignitions than in the native areas. A year after the burn Lehmann lovegrass was not adversely affected, while all of the native grasses present were compromised to some degree, with Black grama exhibiting the most dramatic response. The authors suggest that Lehmann lovegrass has many properties that might encourage an elevated fire regime; increased above-ground production can lead to larger amounts of flammable biomass compared to areas where natives persist; reduced patchiness of the canopy cover in lovegrass patches may allow for easier spread of a fire. [RC]

McIlvanie, S.K. “Grass seedling establishment, and productivity – overgrazed vs. protected range soils.” *Ecology*. 23.2 (1942): 228-231.

[1941] Study done to investigate seedling establishment on rangeland not badly depleted in which establishment of two grasses, Lehmann lovegrass and blue panicgrass (*Panicum antidotale*), was tested on overgrazed and protected rangeland. Lehmann lovegrass seeds became established on the overgrazed soil as rain would incorporate the seeds into the soil, whereas on the protected soil a thin layer of surface algae prevent the seeds from making contact with the mineral soil and germination was prevented for both grasses. [RC]

Medina, A.L. “Diets of scaled quail in southern Arizona.” *Journal of Wildlife Management*. 55.4 (1988): 753- 757.

[1982-84] The diets of scaled quail (*Callipepla squamoto*) in southern Arizona were studied over a two-year period. Seeds of woody plants (57%), and green forbs (39%) were staples in the quails diet. Grass seeds were only eaten in significant amounts from September to November, while insects were eaten mainly from March to August. The quail preferred habitats with low perennial grass cover and high forb cover. Of habitats studied, areas dominated with Lehmann lovegrass provided the lowest perennial grass cover and highest annual plant cover and as such do not provide good foraging habitats for scaled quail. The results show that reseeding of native grasslands with Lehmann lovegrass should be reevaluated with respect to the potential impacts on native flora and fauna. [RC]

Milton, S.J., W.R.J. Dean, GIH Kerley, M.T. Hoffman, and W.G Whitford. “Dispersal of seeds as nest material by the cactus wren.” *The Southwestern Naturalist*. 43.4 (1998): 449-452.

[1998] Common plants used as nest construction materials by the cactus wren (*Campylorhynchus brunneicapillus*) were studied in the southern Chihuahuan Desert. The most common plants used were bush muhly (*Muhlenbergia porteri*), creeping spiderling (*Boerhavia spicata*), and Lehmann lovegrass. Nest material often contains viable seed and the cactus wren’s nest construction may be a means of dispersal of these seeds, including Lehmann lovegrass, for distances up to 65 meters. Cactus wren nests are long-lived and the seeds may be stored for a long period of time. Furthermore, cactus thorns protect the understory from herbivory. As such, dispersal in cactus wren nests may enhance the spread of Lehmann lovegrass, along with other introduced species. [RC]

Moran, M.S., R.L. Scott, E.P. Hamerlynck, K.N. Green, W.E. Emmerich, and C.D. Collins. "Soil evaporation response to Lehmann lovegrass (*Eragrostis lehmanniana*) invasion in a semiarid watershed." *Agricultural and Forest Meteorology*. 149 (2009): 2133-2142.

[2005-2007] In order to quantify the change in surface water balance associated with Lehmann lovegrass the authors measured daily soil evaporation in the Kendall Grassland at the Walnut Gulch Experimental Watershed in southeast Arizona before and after it transitioned from a diverse, native bunchgrass community to a Lehmann lovegrass dominated one. The study found that evapotranspiration for the total season is a function of season-long infiltration regardless of vegetation type. [RC]

O'Dea, M.E. "Influence of mycotrophy on native and introduced grass regeneration in a semiarid grassland following burning." *Restoration Ecology*. 15.1 (2007): 149-155.

[1998-1999] Prescribed burning is used in the southwestern United States as a method to prevent the spread of woody shrubs, but studies have shown this may have the unintended consequence of favoring non-native grass, such as Lehmann lovegrass. Both native and invasive perennial grasses evolved with fire, and their response to mycotrophy following a burn appears to give some species an advantage. A soil bioassay from a southern Arizona grassland showed that soil exposed to a burn had significantly lower mycorrhizal infection percentage than soil not exposed to the burn. A coincident greenhouse experiment showed that *Eragrostis* spp. seedlings (including Lehmann lovegrass) had greater shoot biomass and inflorescence when not infected by mycorrhizal fungi than other non-infected grass species. Furthermore, when lovegrass species were infected with mycorrhizal fungi, they did not develop inflorescence before harvest as other infected species did. The author suggests this data shows that the lack of lovegrass' dependence on mycorrhizal fungi infection for re-establishing itself, giving it an advantage over species that do exhibit this dependence in a post-burn environment, and allowing it to recover in burned areas before the recovery of mycorrhizal fungi. [RC]

Pase, C.P. "Effect of a February burn on Lehmann lovegrass." *Journal of Range Management*. 24 (1971): 454-456.

[1969] It has been shown that summer fires may cause substantial mortality of Lehmann lovegrass (Humphrey & Everson, 1951; Cable, 1965); this study set out to determine effects of a winter burn on Lehmann lovegrass. The burn plot was located in central Arizona, was seeded with Lehmann lovegrass in 1962, and received 0.88 of an inch of rain four days before the February 11 burn. Following the burn there was little adverse effect on Lehmann lovegrass density, mortality, or vigor, although shrub mortality was high. This was probably due to the high moisture content and the resultant quick, flashy top fire that had little effect on the perennating buds near the ground surface. [RC]

Potts, D.L., T.E. Huxman, B.J. Enquist, J.F. Weltzin, and D.G. Williams. "Resilience and resistance of ecosystem functional response to a precipitation pulse in a semi-arid grassland." *Journal of Ecology*. 94 (2006): 23-30.

[2002-2003] In a two-year study to quantify the short- and long-term dynamics of whole ecosystem response to precipitation pulses, one of two experimental plots consisted of Lehmann lovegrass planted in monoculture on loamy-sand and clay geo-morphic soils. Both years, Lehmann lovegrass interacted with the clay geo-morphic soil in a manner that reduced the ecosystem functional resistance. For up to one week following the precipitation pulse, Lehmann lovegrass spread through multivariate space more than natives on the clay soil. It is suggested that this response may be due to the less dense canopies and small amount of plant litter of Lehmann lovegrass, which result in a greater amount of incoming radiation reaching the soil surface. [RC]

Ragotzkie, K.E., and J.A. Bailey. "Desert mule deer use of grazed and ungrazed habitats." *Journal of Range Management*. 44.5 (1991): 487-490.

[1984-86] In a study to determine the use of grazed and ungrazed habitats by desert mule deer (*Odocoileus hemionus crooki*), it was found that the only habitat avoided by desert mule deer on the Santa Rita Experimental Range was grassland dominated by Lehmann lovegrass. [RC]

Robinett, D. "Fire effects on southeastern Arizona plains grasslands." *Rangelands*. 16.4 (1994): 143-148.

[1992] In a study of the effects of fire on southeastern Arizona grasslands, the fire history of Fort Huachuca was examined. The fort is one of the few areas in Arizona that has burned regularly in the last one hundred years and the author examined areas of loamy upland soil, sandy loam upland, loamy hills, and granitic hills that had burned either once since 1977, two or three times since 1977, and five or six times since 1977.

Lehmann lovegrass most favored the sandy loam upland areas. On the areas that had burned five times since 1977, the frequency of Lehmann lovegrass increased from 9% to 96% at the expense of native sideoats grama, black grama, and plains lovegrass. The area that had burned only once had 47 species of plants present, while the area burned five times had 29 and was dominated by Lehmann lovegrass. Frequent burning benefits Lehmann lovegrass and can lead to a monotypic stand. [RC]

Robinett, D. "Lehmann lovegrass and drought in Southern Arizona." *Rangelands*. 14.2 (1992): 100-103.

[1988-1990] Transects were placed in a 5,500-acre pasture of deep, loamy soil where Lehmann lovegrass and native perennials, mostly back grama, existed in an even mixture. Compared to a normal 4.5 inches of rain, the area received less than 0.8 inches from November 1, 1988 to July 15, 1989, with no measurable rain in December of 1988 or January, February, April, May and June of 1989. Both grazed and un-grazed black grama and Lehmann lovegrass had similar mortality rates over the one-third to one-half of the transect that was affected. Below average but adequate summer rainfall was recorded in 1898, followed by 2.49 inches in October. With cooler temperatures, Lehmann lovegrass germinated in the dead patches and by November was well established. By fall of 1990, Lehmann lovegrass had completely occupied the dead patches at the expense of the native grasses black grama, red three-awn, mesa three-awn, and sprucetop grama. The spread of Lehmann lovegrass should be curtailed through restricting vehicular use through desirable areas of native grasses, especially where Lehmann lovegrass is absent. The author suggests that Lehmann lovegrass has been naturalized and ranchers would be wise to learn to take advantage of it while limiting its encroachment. [RC]

Roundy, B.A., and S.H. Biedenbender. "Germination of warm-season grasses under constant and dynamic temperatures." *Journal of Range Management*. 49.5 (1996): 425-431

[1996] Fifteen collections of 10 native and exotic grasses (including three collections of Lehmann lovegrass) were germinated at a constant temperature of 25°C and at gradual and abruptly alternating temperature regimes characteristic of wet seedbeds in the southwest desert grassland in summer, winter, and spring. Two of the Lehmann lovegrass selections had lower total germination under gradual summer temperatures than under constant or abrupt temperatures. All three Lehmann lovegrass collections had much slower germination under constant 25°C than under the gradual or abrupt summer temperatures. Lehmann lovegrass exhibited sensitivity to cool temperature extremes, and that germination may be stimulated by extreme temperature alterations. It is thought that abruptly changing temperatures may break the dormancy of Lehmann lovegrass seeds. [RC]

Roundy, B.A., R.B. Taylorson, and L.B. Sumrall. "Germination responses of Lehmann lovegrass to light." *Journal of Range Management*. 45.1. (1992): 81-84.

[1987-88] Four Lehmann lovegrass seed lots of differing ages (1, 2, at least 3, and at least 4 years old) were tested for germination response to darkness and irradiance with red (R) and far-red (FR) light. Exposure to R after imbibition in darkness greatly increased germination, while irradiation with FR after exposure to R reduced germination. Exposure to R after prolonged exposure to FR slightly increased germination of older seeds and did not increase germination of 1-2 year old seeds. An increase in germination was noted when temperature alternated between 15°C and 38°C, as opposed to a constant 25°C. Emergence of Lehmann lovegrass is greater when the canopy is opened via burning, mowing, or grazing. This is likely a function of red light stimulation of biologically active phytochrome and increase seedbed temperature changes. [RC]

Roundy, A.R., J.A. Young, L.B. Sumrall, and M. Livingston. "Laboratory germination responses of 3 lovegrasses to temperature in relation to seedbed temperatures." *Journal of Range Management*. 45.3 (1992):306-311.

[1987-88] The germination of three lovegrasses (Lehmann, Cochise, and plains) was tested on two semidesert grassland sites in the southwest in relation to an array of constant and alternating temperatures. Both Lehmann and Cochise lovegrasses exhibited high germination rates at temperature alternations similar to wet seedbed temperature extremes in December (0,2/15°C) as well as at moderate temperature alternations similar to wet seedbeds in April (10/30°C). Field observations have confirmed April germination for Lehmann lovegrass, but not December germination. [RC]

Ruyle, G.B., O. Hasson, and R.W. Rice. "The influence of residual stems on biting rates of cattle grazing *Eragrostis lehmanniana* Nees." *Applied Animal Science Behaviour*. 19 (1987): 11-17

[1984-86] The effects of the presence and the height of residual stems on cattle grazing Lehmann lovegrass were studied at the Santa Rita Experimental Range in southern Arizona. It was determined that increased presence and increased height of residual stems increases the time between bites taken by grazing cattle, therefore decreasing bite rates.

As grass tillers became longer and green herbage increased, bite rates increased but still remained lower overall on plants with larger amounts of residual stems. [RC]

Ruyle, G.B., B.A. Roundy, and J.R. Cox. "Effects of burning on germinability of Lehmann lovegrass." *Journal of Range Management*. 41.5 (1988): 404-406.

[1984-85]

The effect of seasonal burning on the germinability of Lehmann lovegrass was measured in a two-year study on the Santa Rita Experimental Range in southern Arizona. Following February, June, July, and November burns, samples of surface soil were taken for bioassay. In those collected from the burned plots, 40% more seedlings emerged than on the unburned plots. This increased germinability associated with fire is thought to be one of numerous factors in the ability of Lehmann lovegrass to re-establish itself after mature plants are killed by burning. [RC]

Ryan, J., S. Miyamoto, and J.L. Stroehlein. "Effect of acidity on germination of some grasses and alfalfa." *Journal of Range Management*. 28.2 (1975): 154-155.

[1973] In petri dishes of pH levels ranging from 7.0 to 1.0, the germination of blue panicgrass (*Panicum antidotale*), buffelgrass (*Penisetum ciliare*), common bermudagrass (*Cynodon dactyl*), alfalfa (*Medicago sativa*), and Lehmann lovegrass was studied. Although the pattern of response was similar for all species, Lehmann lovegrass failed to germinate at pH 3.0, while blue panicgrass, alfalfa and common bermudagrass did germinate at reduced rates. At pH 2.0 only a few alfalfa and blue panicgrass seeds germinated and no others did. At pH 2.0, none of the species were able to germinate. Results suggest that when H_2SO_4 is applied to soils, germination will benefit if seeding is delayed until acid has completely reacted with soil bases. [RC]

Ryan, J., S. Miyamoto, and J.L. Stroehlein. "Salt and specific ion effects on germination of four grasses." *Journal of Range Management*. 28.1 (1975): 61-64.

[1973-74] The effects NaCl, $CaCl_2$, $MgCl_2$, $NaSO_4$, $2H_2O$, and $MgSO_4.7H_2O$ at concentrations of 50, 100, 150, and 200 meq/l were studied on the germination of four grasses commonly used for revegetation; Lehmann lovegrass, blue panicgrass (*Panicum antidotale*), Wilman lovegrass (*Eragrostis superba*), and Weeping lovegrass (*E. curvula*). Increased salt concentrations led to decreased germination rates in all grasses tested, although Weeping and Wilman lovegrass were found to be relatively salt tolerant. Lehmann lovegrass germination was particularly inhibited by Magnesium and Sodium. [RC]

Ryan, J., J.L. Stroehlein, and S. Miyamoto. “Effects of surface-applied sulfuric acid on growth and nutrient availability of five range grasses in calcareous soils.” *Journal of Range Management*. 28.5 (1975): 411-414.

[1973-74] To determine the impacts of sulfuric acid (H_2SO_4) when added to two calcareous soils, a greenhouse pot study examined the growth of five range grasses (including Lehmann lovegrass) in Comoro and Cave soils amended with concentrated sulfuric acid. All species exhibited significant increases in growth following application of sulfuric acid, which is abundant in the southwest from copper smelting. Although all species showed increased growth, the results suggest that Lehmann lovegrass and Wilman lovegrass would be most competitive in iron deficient soils. [RC]

Saucedo, S.M., T.A. Moreno, E. Huber-Sannwald, and J.F. Fores. “Seed germination and seedling growth in native and exotic grasses in the semiarid grasslands of Northern Mexico.” *Tecnica Pecuaria en Mexico*. 47.3 (2009): 299-312.

[2006-2007] Study to compare germination and seedling growth mechanisms in two native species and five exotic species (including Lehmann lovegrass) and identify traits that may be advantageous to exotic species in the semiarid regions of Northern Mexico. Seed used in the study was collected in the Llanos de Ojuelos region of Jalisco state, Mexico during the final annual growth season. The study found Lehmann lovegrass to have the highest seed count per weight (14,720/g); Lehmann lovegrass germination increased when seeds were washed and germination decreased by 84% when unwashed; soil sterilization lead to an increase in leaf and root biomass production in Lehmann lovegrass; SLA of Lehmann lovegrass was higher than other species and increased 100% in sterile soil; pathogenic microorganisms inhibited growth in all studied species with the exception of Lehmann lovegrass. [RC]

Schmutz, E.M., and D.A. Smith. “Successional classification of plants on a desert grassland site in Arizona.” *Journal of Range Management*. 29.6 (1976): 476-379.

[1941, 1969] Vegetative cover, composition, and frequency studies were used to classify a variety of plants in protected and grazed semi-arid grasslands in Arizona as either: 1) decreasers, 2) increasers, or 3) invaders. Along with burroweed and sticky snakeweed, Lehmann lovegrass was classified as an “invader.” [RC]

Schussman, H., E. Geiger, T. Mau-Crimmins, and J. Ward. “Spread and current potential distribution of an alien grass, *Eragrostis lehmanniana* Nees, in the southwestern

USA: comparing historical data and ecological niche models." *Diversity and Distributions*. 12 (2006): 582-592.

[2000] This study set out to compare current locations of Lehmann lovegrass with distribution maps from 1980, and to use ecological niche models to identify potential habitat in Arizona and western New Mexico. Despite the belief in the 1990's that Lehmann lovegrass had reached its ecological limit, it was found that the grass has indeed continued to spread into the new decade. Using two models to predict potential ecological niche, it was found that potential habitat includes 71,843 km^2 and covers a large portion of southeastern and central Arizona, and western New Mexico. Reports of Lehmann lovegrass in northern California, central Texas, and central Chihuahua, Mexico suggest that the species is capable of spreading far beyond areas suggested by the models used in this study. Data shows that Lehmann lovegrass may not be a good competitor at the tail ends of its distribution and may not be able to dominate there, and while it can spread to a variety of soil types it only dominates when soils are sandy. Lehmann lovegrass is expected to continue to spread, and climate change, land use practices, and phenotypic plasticity may be important players in this spread. [RC]

Smith, S.E., D.M. Fendenheim, K. Halbrook. "Epidermal conductance as a component of dehydration avoidance in Digitaria californica and Eragrostis lehmanniana, perennial desert grasses." *Journal of Arid Environments.* 64.2 (2006): 238-250.

[2001-2003] Studied the epidermal conductance of Arizona cottontop (*Digitaria californica*) and Lehmann lovegrass to determine if low epidermal conductance affects survival of perennial grasses during drought through maintenance of tissue hydration. In Arizona epidermal conductance was lower in Lehman lovegrass than in Arizona cottontop, and shoot biomass production as a fraction of epidermal conductance was found to be higher in Lehmann lovegrass than in Arizona cottontop. These results suggest that epidermal conductance may be lower in perennial grasses from more arid environments where drought is severe, and may be a component of drought tolerance. [RC]

Stubbendieck, J., P.T. Koshi, and W.G. McCully. "Establishment and growth of selected grasses." *Journal of Range Management*. 26.1 (1973): 39-41.

[1969-70] The effect of cotton-bur mulch and manure on the establishment and growth of 13 grasses (including Lehmann lovegrass) was measured at the U.S. Big Spring Field Station in Big Spring, Texas. In 1969 the number of Lehmann lovegrass seedlings was significantly higher in the no mulch treatment and lowest in cotton-bur mulch treatment, while no significant differences were noted in 1970. Average height of established Lehmann lovegrass plants were highest in 1970 in the manure treatment and lowest in the no mulch treatment. Studies indicate that while manure and mulch treatments may negatively impact seedling numbers and plant height the year of seeding, this is offset by the second growing season due to improved soil-plant-water relations. [RC]

Suding, K.N., K.L. Gross, and G.R. Houseman. "Alternative states and positive feedbacks in restoration ecology." *Trends in Ecology and Evolution*. 19.1 (2004): 46-53.

[2003] As the amount of degraded land increases, so does the interest in the development of better predictive tools and broader guiding framework. Traditional efforts of restoring historical disturbance regimes and abiotic factors, and relying on successional processes to guide biotic recovery are hitting constraints. Strong feedbacks between biota and the physical environment can alter efficacy, and experimental work suggests that degraded systems can be resilient to traditional restoration efforts. As a result, ecosystem models that incorporate system thresholds and feedbacks are now being applied toward efforts to recover degraded lands (such as those invaded by Lehmann lovegrass) and are suggesting ways in which restoration efforts can identify, prioritize and address these hindering constraints. [RC]

Sumrall, L.B., B.A. Roundy, J.R. Cox, and V.K. Winkel. "Influence of canopy removal by burning or clipping on emergence of *Eragrostis lehmanniana* seedlings." *International Journal of Wildland Fire*. 1 (1991): 35-40.

[1987-88] To determine why high seedling recruitment of Lehmann lovegrass follows fire, germination in both seedbank and field were measured following either no treatment, burning, clipping and herbicide, or herbicide only. It was found that canopy removal (clipping or burning) resulted in increased seedling emergence in seedbank samples and greatly increased field seed emergence. These results are most likely due to the greater range of diurnal soil temperatures as well as increases in red light reaching the seedbed following canopy removal, both of which have been shown to stimulate germination. [RC]

Tapia, C.R., and E.M. Schmutz. "Germination responses of three desert grasses to moisture stress and light." *Journal of Range Management*. 24.4 (1974): 292-295.

[1973] In this study of Lehmann lovegrass, Arizona cottontop, and Plains bristlegrass, it was found that Lehmann lovegrass was quite susceptible to physiological drought. Lehmann lovegrass was the fastest to germinate, and it was indicated that the adaptability and responsiveness of Lehmann lovegrass is due to its ability to germinate rapidly. Lehmann lovegrass germination was adversely affected by total darkness, indicating the need for shallow planting. In the arid southwest where rain is scarce, quick germination of Lehmann lovegrass provides it with the competitive edge necessary to establish itself faster than bristlegrass and cottontop. [RC]

Tiedemann, A.R., and J.O. Klemmedson. "Response of desert grassland vegetation to mesquite removal and regrowth." *Journal of Range Management*. 57.5 (2004): 455-465.

[1967, 1981, 1991] In 1966, three different treatments were applied to velvet mesquite (*Prosopis juliflora*); left intact, mesquite removed and litter left intact, and mesquite removed and litter removed. Vegetation responses to litter removal were also examined. In mesquite left intact treatment plots, Lehmann lovegrass was most abundant in open locations between mesquites and was least abundant under mesquite canopies. The combination of mesquite removed and litter left intact treatments favored increases in cover development of native perennials, while litter removal increased cover of Lehmann lovegrass (possibly due to increased amount of red light and soil temperature variability). Canopies in the mesquite intact treatment appear to help maintain diversity and mature mesquite should be looked at as a refuge for native species. [RC]

Tixier, J.S., D.R. Kincaid, G.A. Holt, and P.D. Dalton. "The spread of Lehmann lovegrass as affected by mesquite and native perennial grasses." *Ecology*. 40.4 (1959): 738-742.

[1958] This study took place on the Santa Rita Experimental Range and set out to determine the effect of velvet mesquite (*Prosopis juliflora*) on Lehmann lovegrass, the effect of velvet mesquite on native perennial grasses, and the result of competition between Lehmann lovegrass and native perennial grasses. It was found that velvet mesquite densities of less than 25 trees per acre did not significantly reduce Lehmann lovegrass establishment. The removal of velvet mesquite along with seeding of Lehmann lovegrass would simply replace one source of competition with another source. Furthermore, Lehmann lovegrass has the ability to reduce and eventually replace native grasses and in areas where Lehmann lovegrass has not invaded grass density is equal to or higher than mixed Lehmann lovegrass-native areas. [RC]

Venter, J.A., and L.H. Watson. "Feeding and habitat use of buffalo (*Syncerus caffer caffer*) in the Nama-Karoo, South Africa." *South African Journal of Wildlife Research*. 38.1 (2008): 42-51.

[2002-2003] The authors aimed to determine the diet and habitat of use of grazing buffalo (*Syncerus caffer caffer*) on the Doornkloof Nature Reserve in the Nama-Karoo, South Africa. It was found that seven species of grass formed the bulk of the buffalo's diet and of these Lehmann lovegrass formed the largest part (30.9%). Lehmann lovegrass availability was highest in habitat used during the wet season and low in habitat used during the dry season, and was thus used largely during the wet season. During the dry season, Lehmann lovegrass was replaced by kangaroo grass (*Themeda triandra*) as the largest used grass. [RC]

Voigt, P.W., B.L. Burson, and R.A. Sherman. "Mode of reproduction in cytotypes of Lehmann lovegrass." *Crop Science*. 32 (1992): 118-121.

[1989-90] All known sources of Lehmann lovegrass reproduce asexually. This study was conducted to locate sexual germplasm and describe the reproductive process in Lehmann lovegrass. Self-fertility, open-pollinated seed set, and mode of reproduction by progeny were evaluated in ten Lehmann lovegrass accessions. Three were found to be diploid while two were tetraploid. Triploid plants were found in the primarily diploid accessions, most likely the result of either union of reduced and unreduced gametes or from fertilized diploid plants by nearby Lehmann lovegrass plants. Diploid plants were sexual, while triploid and tetraploid plants were facultative diplosporous apomicts. Although some diploid plants had obvious morphological differences, these were not sufficient enough to differentiate genetic from environmental variation. [RC]

Voight, P.W., L.I. Croy, and F. Horn. "Forage quality of winterhardy lovegrasses." *Journal of Range Management.* 39.3 (1986): 276-280.

[1969-72] The germplasms of various selections of Lehmann lovegrass and Weeping lovegrass (*Eragrostis curvula*) were studied to determine in vitro dry matter disappearance (IVDMD), palatability, and forage vigor. Average IVDMD was higher for Lehmann lovegrass, while it was generally less productive and less palatable. Within the Lehmann lovegrass studied, the more vigorous selections tended to be lower in IVDMD and less palatable than less productive selections. [RC]

Whitford, G. "Desertification and animal biodiversity in the desert grasslands of North America." *Journal of Arid Environments.* 37.4 (1997): 709-720.

[1990-94] Study to examine the species composition, relative abundances, and diversity patterns of breeding birds and small mammals in a series of sites representing varying degrees of desertification. Avian diversity was studied on native grass sites and Lehmann lovegrass infested sites on the Santa Rita Experimental Range (SRER) south of Tucson, AZ as well as the Empire Cienega Ranch near Sonoita, AZ. It was found that the

Lehmann lovegrass dominated areas of the SRER had lower avian species richness, abundance, and diversity indices than the native grass areas. Avian species richness was higher on Lehmann lovegrass areas on the Empire Cienega Ranch than on native sites, although the author notes that this appeared to be attributable to one sample location within 200 m of a well. The Lehmann lovegrass sites on the Empire Cienega Ranch exhibited a mix of native grasses, forbs, and sub-shrubs, whereas the SRER sites were virtual Lehmann lovegrass monocultures. [RC]

Whitford, W.G., G.S. Forbes, and G.I. Kerley. "Diversity, spatial variability, and functional roles of invertebrates in desert grassland ecosystems." *The Desert Grassland.* Ed. Mitchel P. McClaran and Thomas R. Van Devender. Tucson: University of Arizona Press, 1995. 152-195.

[1989] In an analysis of desert grassland invertebrates on the Jornada del Muerto Basin Study Area in New Mexico, the authors found that there is no obvious difference between the abundance and diversity of invertebrate soil micro-arthropods found in the rhizasphere of Lehmann lovegrass and native black grama grass (*Bouteloua eripoda*). Although both plants produce organic matter similar in quality and quantity, the authors note that vegetation composition has little effect on soil micro-arthropods. [RC]

Whitford, W.G., J. van Zee, M.S. Nash, W.E. Smith, and J.E. Herrick. "Ants as indicators of exposure to environmental stressors in North American desert grasslands." *Environmental Monitoring and Assessment*. 54 (1999): 143-171.

[1993-94] In a study to determine if ants can be used as reliable indicators of exposure to stress, ecosystem health, rehabilitation success, or faunal biodiversity, the relative abundance of ant species was measured at 44 sites in southern New Mexico and southeastern Arizona. Sites were chosen based on exposure to disturbance, varying intensities of grazing, dominance by an exotic species, and vegetation change due to restoration or disturbance; two rangeland sites were at the Empire Cienega Ranch and two were at the Santa Rita Range Reserve. On the Empire Cienega Ranch, ant species richness was higher in areas dominated by Lehmann lovegrass than in native grassland. *Aphaenogaster cockerelli* made up 11% of the population in native grassland on the Santa Rita, and only 1% in native areas. On both ranches species diversity was nearly equal although in Lehmann lovegrass dominated areas large seed harvesting ant (*Pogonomyrmex* spp.) numbers were significantly lower. This might be because Lehmann lovegrass seeds are very small and not suitable for large harvesters, as well as the lack of large seed producing spring annual plants. There was no difference between Lehmann lovegrass and native areas in relation to species richness or relative abundance of small seed harvesters (*Pheidole* spp.), small generalists, tolerant genera, or intolerant genera. In areas dominated by Lehmann lovegrass, ant metrics did not differ from native grasslands other than a significant decrease in abundance of large seed harvesting ants (*Poronomyrmex* spp.). [RC]

Winkel, V.K., and B.A. Roundy. "A technique to determine seed location in relation to seedbed preparation treatments." *Journal of Range Management*. 44.1 (1991): 91 92

[1989] Describes a then-new technique for determining seed location in a variety of seedbed preparations through wetting the soil, extracting soil cores, and locating seeds with a dissecting scope. Buried Lehmann lovegrass seeds, it is noted, may be too small for visual detection and their percentage can be underestimated. [RC]

Winkel, V.K., and B.A. Roundy. "Effects of cattle trampling and mechanical seedbed preparation on grass seedling emergence." *Journal of Range Management*. 44.2 (1991): 176-180.

[1987-89] To determine whether cattle trampling is an effective means of establishing seeds for a variety of grasses (including Lehmann lovegrass and Cochise lovegrass), seedling emergence from broadcast-seeded lightly and heavily trampled, undisturbed, land imprinted, and root-plowed seedbeds were compared. Beds were treated and seeded prior to summer rains on sandy loam soil. When surface soil water was available for at least 24 consecutive days, imprinting increased emergence of Cochise lovegrass and Lehmann lovegrass emergence was high on undisturbed plots. Root-plowing decreased Lehmann lovegrass emergence as up to 60% of the seeds were buried too deeply. In general, the results showed that seedling emergence is related more to patterns of soil water availability than to seed-bed treatment, and seedling emergence will increase with more rainfall regardless of treatment. [RC]

Winkel, V.K., B.A. Roundy, and D.K. Blough. "Effects of seedbed preparation and cattle trampling on burial of grass seeds." *Journal of Range Management*. 44.2 (1991): 171-175.

[1987-88] Study set out to determine the effects of trampling by livestock and mechanical seedbed preparation on burial of grass seed on a sandy loam seedbed. Beds were root plowed or ripped before broadcast seeded with Lehmann lovegrass, sideoats grama, blue panic, or Cochise lovegrass, or broadcast seeded then trampled by cattle (lightly or heavily) or land imprinted before summer rains. Heavy trampling buried the most Lehmann lovegrass seeds, followed by imprinting, light trampling, and no disturbance. High percentage of seeds of seeds were buried on plots that were heavily trampled, imprinted, and root plowed or ripped, many of these were buried to deep to emerge. Lehmann lovegrass, due to its small seed, was more easily buried with treatment and rain. [RC]

Winkel, V.K., B.A. Roundy, and J.R. Cox. "Influence of seedbed microsite characteristics on grass seedling emergence." *Journal of Range Management*. 44.3 (1991): 210-214.

[1990] Studied the influence of microsite characteristics and soil water treatments on seedling emergence of three grasses, including a cultivar of Lehmann lovegrass, Cochise lovegrass (*Lehmann lovegrass* X *E. tricophera*). All three species had higher emergences from gravel, followed by plant litter, cracks in the soil, and the bare soil surface (which decreased in water content faster than other sites). Minimal seedbed preparation is necessary for Cochise lovegrass to establish itself on coarse-textured and gravelly soils. In gravelly soil, Cochise lovegrass emerged under all three water treatments, which included watering everyday, watering on day 1 and 5, and watering only on day 1. [RC]

Williams, D.G., and Z. Baruch. "African grass invasion in the Americas: ecosystem consequences and the role of ecophysiology." *Biological Invasions*. 2 (2000): 123-140.

[1999] The intentional introduction of African grasses now constitutes a significant threat to biological diversity in the tropics, subtropics and warm temperate regions of the Americas. The invaded ecosystems tend to be biologically impoverished with the effects of the invasion, which are often related to the loss of woody species and changes in the fire regime, although the ecophysiological attributes of African grasses (high biomass allocation in leaves, high growth rate, and high leaf-level gas exchange rates) also have important consequences. These attributes may potentially affect ecosystem function through alteration of production or trophic structure; alteration of microclimates and shifting rates of consumption and supply of light, water and mineral nutrients; increase the frequency and intensity of fire; alteration of competitive interactions; and compromising the stability of ecosystems. Future global changes that may affect African grass invasions include increased co_2 concentration and the resultant increased growth rates, as well as climate warming, precipitation redistribution, and enhanced levels of nitrogen deposition that together pose the risk of increasing the rate of spread of these African invaders. [RC]

Wright, L.N. "Seed dormancy, germination environment, and seed structure of Lehmann lovegrass, *Eragrostis lehmanniana* Nees." *Crop Science.* 13 (1973): 432-435.

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[1971] Investigated the efficiency of water use by Lehmann lovegrass, the seedling drought tolerance and efficiency of water use relationship, as well as the association of transpired water, dry matter production, stomate density, and petroleum ether extract with efficiency of water use and seedling drought tolerance. Lehmann lovegrass is relatively efficient in its use of water when compared with other plants, its seedlings exhibit high drought survival, and a significant association between seedling drought tolerance and area of deflection of petroleum ether extract was found. [RC]

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