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# INFLUENCE OF CLIMATIC AND EDAPHIC FACTORS ON THE DISTRIBUTION OF *ERAGROSTIS LEHMANNIANA* NEES IN ARIZONA, USA

## *INVLOED VAN KLIMAAT EN EDAFIESE FAKTORE OP DIE VERSPREIDING VAN* ERAGROSTIS LEHMANNIANA *NEES IN ARIZONA, VSA*

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## ABSTRACT

Lehmann lovegrass (*Eragrostis lehmanniana* Nees) was introduced into Arizona, USA, from South Africa in 1932 and has since been sown throughout the southwestern USA and Northern Mexico. The species is well adapted in southeastern Arizona where it has been sown on over 69 115 ha and has spread by seed to an additional 76 040 ha. Where Lehmann lovegrass predominates and spreads, surface soils are sandy, summer rainfall is greater than or equal to 200 mm and winter temperatures rarely fall below 0° C. Factors contributing to the spread of Lehmann lovegrass in southeastern Arizona include fire, cattle grazing and drought.

## *UITTREKSEL*

Eragrostis lehmanniana *Nees is in 1932 in Arizona, VSA, aangeplant deur middel van saad afkomstig vanuit Suid-Afrika, en is sedertdien ook oral in die suid-westelike VSA en Noordelike Meksiko gesaai. Die spesie is goed aangepas in die suid-oostelike gedeeltes van Arizona waar dit ingesaai is op 69 115 ha en het reeds deur middel van saad versprei tot 'n addisionele 76 040 ha.*

*Die gras domineer en versprei veral in gebiede waar die gronde sanderig is, somer reënval hoër is as 200 mm en winter temperature nie onder 0°C daal nie. Ander faktore wat bydrae tot die verspreiding van* E. lehmanniana *in Arizona, sluit vuur, beweiding en droogte in.*

Additional index words: Cattle grazing; fire; plant invasion; rangeland revegetation and seed germination.

## INTRODUCTION

Lehmann lovegrass (*Eragrostis lehmanniana* Nees) a subclimax, perennial, warm-season bunchgrass is native to the semiarid lands in the Northern Cape of South Africa (Fourie & Roberts, 1976). Where Lehmann lovegrass occurs the elevation varies from approximately 800 to 1 500 m, and annual precipitation varies from approximately 250 to 500 mm. Summer precipitation is more abundant and dependable than winter precipitation. Huntley (1984) classified the semiarid Northern Cape area as either Karoo or arid savanna. Surface soils in the Karoo are sandy and covered with gravel. Surface soils in the arid savanna are sandy but caliche ($CaCO_3$) and dolomite ($Mg(CO_3)_2$) outcrops are common (Fourie & Roberts, 1977; Huntley, 1984).

In 1932, F J Crider, Director of the Boyce Thompson Southwestern Arboretum at Superior, Arizona (USA) received Lehmann lovegrass seed collected in the Griqualand West Region of South Africa (Crider, 1945). Crider planted Lehmann lovegrass seed on the arboretum grounds and observed that seedlings produced seedheads during the first year of growth (Crider, 1945). In 1935 Crider organized a series of screening tests at the Plant Materials Nursery, US Dep Agric — Soil Conservation Service (USDA-SCS), in Tucson, Arizona. Of the many Lehmann lovegrass accessions tested, Crider selected one that matured quickly and produced abundant seed under irrigation. The accession was named "A-68", and the USDA-SCS initiated a seed production program in 1937.

Between 1937 and 1950 approximately 136 kg of Lehmann lovegrass seed were produced at Tucson and distributed to soil conservationists and scientists within USDA-SCS for field plantings. By 1940 Lehmann lovegrass seed had been sown in Arizona, New Mexico and Texas (Cox, Morton, Johnsen, Jordan, Martin & Fierro, 1982). Between 1940 and 1950 the grass began to appear on areas which had not been seeded.

Early seeding successes sparked interest and the demand for Lehmann lovegrass seed exceeded what USDA-SCS could supply. Between 1951 and 1984 the USDA-SCS provided 1 197 kg of Lehmann lovegrass seed to commercial seed growers, and commercial growers produced 75 069 kg. Approximately 70% of the commercially available seed was sown on rangeland and along highways in Arizona, New Mexico and Texas. The majority of the remaining seed was transported to Mexico and planted in the northern frontier states of Chihuahua, Coahuila and Sonora (Cota & Johnson, 1975; Sanchez, 1976, Cox et al. 1982).

The purpose of this paper is:

1 To delineate areas where Lehmann lovegrass has been successfully established from sown seed, where mature plants have persisted for more than 10 years, and where seed produced from mature plants has colonized new areas,

2 To describe factors which have contributed to the spread of Lehmann lovegrass and,

3 To discuss relationships between soils and climate which may influence the long-term persistence of Lehmann lovegrass in Arizona, USA.

## PROCEDURE

USDA-SCS rangeland conservationists in Arizona provided estimations of the area sown to Lehmann lovegrass by private land owners and adjacent areas colonized by Lehmann lovegrass. Initial plant establishment from seed was documented at 40 sites; 33 in southeastern Arizona, 5 in southern New Mexico, 1 in west Texas (all in USA) and 1 in central Chihuahua, Mexico. Since established plant populations have dramatically increased only in southeastern Arizona our distribution map will be confined to that geographic area. The authors obtained estimated acreages sown to Lehmann lovegrass by Federal and State agencies, and then visited each site to estimate colonized areas. In some instances planting records were unavailable but Lehmann lovegrass stands had been present for 10 years or more.

To determine the accuracy of our distribution area we obtained aerial photographs for 3 sites, and compared actual with estimated areas. Areas dominated by Lehmann lovegrass as determined from aerial photographs, were 5 to 10% greater than area estimates provided to or determined by the authors. Therefore, area estimates presented in this paper may slightly underestimate the current distribution of Lehmann lovegrass on rangelands in southeastern Arizona.

Lehmann lovegrass seed has also been sown on disturbed sites adjacent to primary (Interstate) and secondary (2 lane) roads and along powerlines and pipelines since 1965. Estimates for these areas were provided by the State Office of Transportation in Tucson, Arizona and taken from maps printed by the Arizona Department of Commerce in Phoenix, Arizona.

Climatic and edaphic data were collected at or near the 33 planting sites where Lehmann lovegrass was initially established. Planting sites were visited to determine stand persistence. Lehmann lovegrass plantings were considered successful if (a) seed produced from initially established plants colonized adjacent un-sown areas and (b) densities on both sown and un-sown areas exceeded 5 plants/m² 10 years after planting.

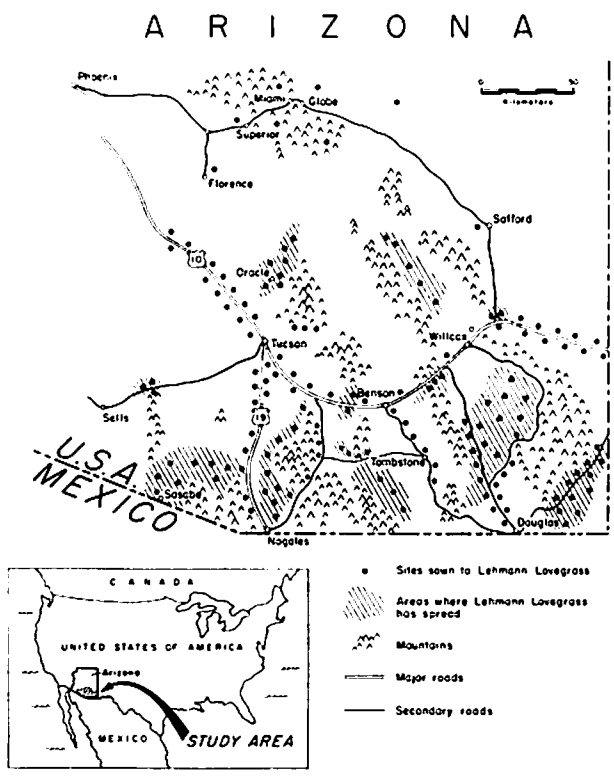



Figure 1 *The distribution of Lehmann lovegrass in southeastern Arizona, USA.*

## RESULTS AND DISCUSSION

### *Areas of Distribution*

Lehmann lovegrass seed sown in central Arizona (Judd & Judd, 1976) extreme southeastern Arizona (Cox & Jordan, 1983) western New Mexico (Bridges, 1941), central and eastern New Mexico (Herbel, Abernathy, Yarbrough & Gardner, 1973) and southwestern Texas (Cox et al. 1982) emerged and produced plants if initial growing season precipitation was greater than 175 mm. Whether grazed or ungrazed, established populations in these areas usually disappeared within 5 years (Cox et al. 1982). In contrast, established populations in southeastern Arizona have persisted, and invaded semidesert grasslands and semidesert shrublands (Anderson, Hamilton, Reynolds & Humphrey, 1957; Cable, 1971).

The current distribution of Lehmann lovegrass in southeastern Arizona is presented in Figure 1, and major stands are located in the counties of Cochise, Graham, Pima, Pinal and Santa Cruz. Surface soils on these sites in shaded areas vary from sand to sand loams, elevations range from 1 000 to 1 600 m, and winter temperatures rarely fall below 0° C (Gelderman, 1972: Seller & Hill, 1974, Soil Taxonomy, 1975: Richmond, 1976; Richardson, Clemmons & Walker, 1979). The hectares sown to and colonized by Lehmann lovegrass within each county is presented in Table 1.

Table 1 *The distribution of Lehmann lovegrass in five southeastern Arizona counties in fall 1984.*[1].

| County | Land Owner or Manager | Area in Hectares | | |
|---|---|---|---|---|
| | | Seeded[2] | Spread To[3] | Total[4] |
| Cochise | Private Ranchers (USDA-SCS) plus Fort Huachuca (US Army) | 25 200 | 30 000 | 55 200 |
| | Bureau of Land Management (USDI) plus University of Arizona | 240 | 0 | 240 |
| | Forest Service (USDA) | 100 | 500 | 600 |
| | Subtotal | 25 540 | 30 500 | 56 040 |
| Graham | Private Ranchers (USDA-SCS) | 5 000 | 5 000 | 10 000 |
| | Bureau of Land Management (USDI) | 200 | - 200 | 0 |
| | Subtotal | 5 200 | 4 800 | 10 000 |
| Pima | Private Ranchers (USDA-SCS) | 25 600 | 13 050 | 38 650 |
| | City of Tucson | 200 | 400 | 600 |
| | City of Green Valley | 0 | 400 | 400 |
| | Davis-Monthan (US Air Force) | 0 | 600 | 600 |
| | Bureau of Indian Affairs (USDI) | 400 | 1 600 | 2 000 |
| | National Park Service (USDI) | 0 | 400 | 400 |
| | Forest Service (USDA) | 920 | 8 800 | 9 720 |
| | Subtotal | 27 120 | 25 250 | 52 370 |
| Pinal | Private Ranchers (USDA-SCS) | 6 465 | - 965[5] | 5 505 |
| | Forest Service | 200 | 200 | 400 |
| | Subtotal | 6 665 | - 760 | 5 905 |
| Santa Cruz | Private Ranchers (USDA-SCS) | 2 430 | 10 370 | 12 800 |
| | Forest Service | 2 160 | 5 880 | 8 040 |
| | Subtotal | 4 590 | 16 250 | 20 840 |
| | Total | 69 115 | 76 040 | 145 155 |

[1] Where densities exceeded 5 plants/m² Lehmann lovegrass was considered the dominant vegetation component.

[2] Areas sown between 1937 and 1984.

[3] Areas where seed produced at sown sites has spread to adjacent un-sown areas.

[4] The summation of 1 and 2.

[5] The area within a sown site where plants died after initial establishment.

Since 1937 Lehmann lovegrass has been successfully established on more than 69 000 ha and has spread by seed to an additional 76 000 ha in southeastern Arizona (Table 1). Private land owners in cooperation with USDA-SCS have sown almost 65 000 ha or 94% of the seeded areas. The total area on which Lehmann lovegrass is the major plant species is currently about 145 000 ha. The annual summer growing season production of Lehmann lovegrass has been estimated to vary from 1 500 to 2 000 kg/ha (Cable, 1976; Sanchez, 1976). These estimates are consistent with data collected in South Africa (Fourie & Roberts, 1976).

*Distribution Factors*

Apparently there are five major factors which have significantly contributed to the spread of Lehmann lovegrass in southeastern Arizona. These include direct and indirect factors.

Direct factors

1 Mechanical soil disturbance and sowing.

Perennial shrubs dominated the majority of the 69 115 ha (Table 1) successfully sown to Lehmann lovegrass. Mechanical treatments were used to reduce shrub competition, increase water infiltration and prepare a seedbed to enhance Lehmann lovegrass seed germination and seedling growth.

Mechanical soil disturbance due to highway, pipeline, and powerline construction began to accelerate after 1960 in southeastern Arizona. Because of soil erosion on disturbed areas the Arizona Department of Transportation began to seed Lehmann lovegrass in 1965. The majority of the seeded area (75%) was along Interstate 10 between Tucson and the New Mexico Border, and along Interstate 19 between Tucson and Nogales, Mexico. Approximately, 3 060 kg of Lehmann lovegrass seed have been sown along highways in southeastern Arizona.

The total land area successfully sown to improve rangeland is more than 31 times greater (Table 1) than that area sown along highway, pipeline (400 ha) and powerline (100 ha) rights-of-way. However, the spread of Lehmann lovegrass may be more closely related to plantings along rights-of-way than rangeland plantings because highway, pipeline, and powerline plantings established continuous corridors into rangelands, and traverse many environmental gradients, whereas field plantings were made in rectangular shapes and were confined to localized areas.

2 Chemical brush control.

Cable & Tschirley (1961) reduced mesquite (*Prosopis juliflora*) competition with a herbicide and aerially applied Lehmann lovegrass seed to treated and untreated areas in May 1954. Lehmann lovegrass production was nil in the treated and untreated areas in fall 1954. Production increased from 125 kg/ha in fall 1955 to 475 kg/ha in fall 1959 on treated areas, and from 20 kg/ha in fall 1955 to 210 kg/ha in 1959 on untreated areas. Native grass production during the same period varied from 350 to 910 kg/ha on the treated, and from 130 to 740 kg/ha on the untreated areas.

Cable (1975) re-evaluated the study 21 years post-treatment and found that Lehmann lovegrass had replaced native grasses on both treated and untreated areas. Cable (1976) speculated that Lehmann lovegrass would invade native grasslands at elevations between 1 200 and 1 500 m with or without chemical or mechanical brush control.

Indirect factors

1 Fire

Natural or man-caused fires that occur prior to the summer growing-season (June), when the soil profile is dry, are known to kill mature Lehmann lovegrass plants (Humphrey & Everson, 1951; Cable, 1965; 1967). However, plant populations do not decline because new seedlings from seed which germinate during the summer growing-season replace dead plants. Where native grasses occur, fire creates bare areas that are quickly colonized by Lehmann lovegrass.

2 Cattle grazing

In pastures where Lehmann lovegrass occurs with native grasses, selective cattle grazing may favour the establishment and spread of Lehmann lovegrass. Under conventional year-long grazing management cattle prefer native grasses during the summer growing-season and lightly graze Lehmann lovegrass (Martin, 1983). In contrast, cattle utilize Lehmann lovegrass in fall, winter and spring because the foliage remains green longer than the dormant native grasses (Cable & Bohning, 1959). This seasonal pattern of animal selectivity reduces native-grass vigor, because plants are repeatedly grazed primarily during active growth. Consequently, Lehmann lovegrass may obtain a competitive advantage.

3 Drought

Lehmann lovegrass plants growing on shallow soils are apparently susceptible to drought. About 90% of the plant population on shallow soils died during a mid-summer drought in South Africa, but seedlings quickly re-occupied the site when soil moisture conditions improved (Fourie & Roberts, 1977).

Drought conditions prevailed in southeastern Arizona during the 1950's and 1970's. Observations made during the droughts indicated a substantial decline in native and Lehmann lovegrass populations. When soil moisture improved, native grasses did not re-establish and Lehmann lovegrass completely re-occupied the sites, conditions similar to those created by fires.

*Relationships between soils, temperature, precipitation and Lehmann lovegrass spread.*

Surface soils at the 33 sites where Lehmann lovegrass was successfully established in southeastern Arizona are sand to sand loams and vary from 0 to 120 cm deep. At sites 1-13 (Table 2) the sand to sand loam surface soils are at least 15 cm deep, the soil profile is greater than 50 cm deep and soils are well drained. Soils are classified as either Comoro, Forest, Sonoita, Tubac or Whitehouse series (Soil Taxonomy, 1975; Richmond, 1976; Richardson et al., 1979). Surface soils at sites 14-33 are also sandy, but are either less than 6 cm or greater than 30 cm deep.

Elevation, mean annual winter temperature and mean summer precipitation for the 33 planting sites are provided in Table 2. Elevation is less than 1 000 m at 6 sites, greater than 1 000 and less than 1 500 m at 21 sites and greater than 1 500 m at 6 sites. Annual winter temperatures are less than 12° C at 8 sites, greater than 12 and less than 14° C at 21 sites and greater than 14° C at 21 sites and greater than 14° C at 4 sites. Total summer precipitation is less than 200 mm at 13 sites, greater than 200 and less than 250 mm at 15 sites, and greater than 250 mm at 5 sites.

In Figure 2 groupings of the 33 sites are outlined where, after initial seedling establishment, Lehmann lovegrass populations either colonized new areas and remained on the initially-sown areas (A), remained only on the initially-sown areas, (B) or died (C). Apparently, Lehmann lovegrass has primarily colonized new areas where mean annual winter air temperatures range between 12 and 14° C and where total summer rainfall ranges between 200 and 300 mm.

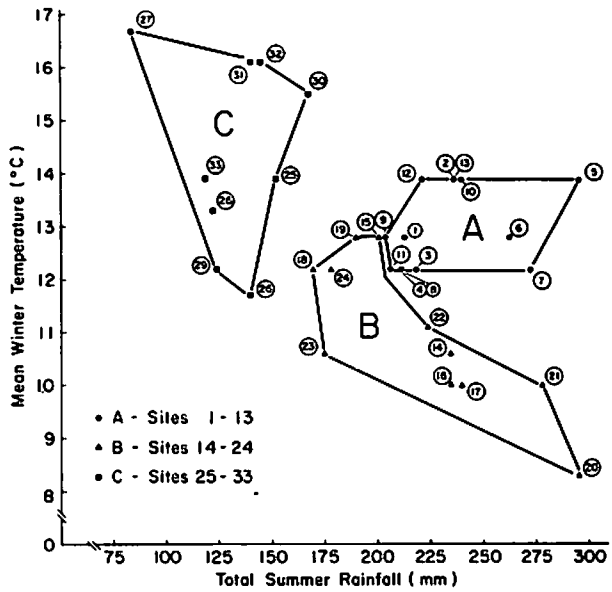
Mean summer (June-September) rainfall and mean winter (October-May) air temperatures at the 33 climatic stations (Sellers & Hill, 1974) near the 33 sites where Lehmann lovegrass was successfully established between 1940 and 1975 indicates summer rainfall is greater than or equal to 200 mm in 8 of 10 years at sites 1-17 and 20-22 (Figure 2). Stands have vigorously spread out of the sown areas at sites 1-11 and 13. Failure to spread in the upper San Pedro Valley between Benson and Tombstone (site 12) may be related to shrub densities, which exceed 4 plants/m$^2$.

Table 2 *Location, elevation, mean annual winter (October-May) temperature, mean annual summer (June-September) precipitation and years of record for 33 climatic stations near 33 sites where Lehmann lovegrass was successfully established in Southeastern Arizona, USA*[1].

| Location | Station and site Number | Elevation (m) | $\bar{X}$ Annual Winter Temp (°C) | Years of Record | $\bar{X}$ Annual Summer ppt. (mm) | Years of Record |
|---|---|---|---|---|---|---|
| Apache Powder Camp | 1 | 1135 | 12,8 | 29 | 213 | 42 |
| Desert Grassland | 2 | 1215 | 13,9[2] | 0 | 236 | 42 |
| Douglas Airport | 3 | 1260 | 12,2 | 25 | 218 | 25 |
| Dos Cabezas | 4 | 1570 | 12,2[2] | 0 | 211 | 22 |
| Florida Canyon | 5 | 1320 | 13,9 | 42 | 295 | 42 |
| Fort Huachuca | 6 | 1435 | 12,8 | 19 | 262 | 19 |
| Nogales | 7 | 1170 | 12,2 | 42 | 272 | 42 |
| Oracle | 8 | 1400 | 12,2 | 42 | 211 | 42 |
| Pierce | 9 | 1360 | 12,8 | 23 | 203 | 23 |
| Ruela | 10 | 1230 | 13,9[2] | 0 | 239 | 42 |
| Stephens Ranch | 11 | 1230 | 12,2[2] | 0 | 206 | 42 |
| Tombstone | 12 | 1420 | 13,9 | 42 | 221 | 42 |
| Tumacacori National Monument | 13 | 1005 | 13,9 | 27 | 236 | 27 |
| Apache 6 WNW | 14 | 1650 | 10,6 | 8 | 234 | 8 |
| Benson | 15 | 1105 | 12,8 | 42 | 201 | 42 |
| Canelo | 16 | 1535 | 10,0 | 42 | 234 | 42 |
| Cochise Stronghold | 17 | 1460 | 10,0 | 13 | 239 | 13 |
| Fort Grant | 18 | 1500 | 12,2 | 27 | 170 | 42 |
| Miami | 19 | 1090 | 12,8 | 42 | 190 | 42 |
| Portal | 20 | 1635 | 8,3 | 31 | 295 | 37 |
| San Rafeal | 21 | 1460 | 10,0 | 19 | 277 | 38 |
| Sierra Ancha | 22 | 1570 | 11,1 | 38 | 223 | 38 |
| Wilcox | 23 | 1285 | 10,6 | 42 | 175 | 42 |
| Willows Springs Ranch | 24 | 1135 | 12,2 | 25 | 178 | 25 |
| Congress | 25 | 1970 | 13,9 | 26 | 152 | 26 |
| Cordes | 26 | 1160 | 11,7 | 41 | 140 | 42 |
| Florence | 27 | 465 | 16,7 | 42 | 84 | 42 |
| Safford | 28 | 890 | 13,3 | 42 | 122 | 42 |
| San Simon | 29 | 1110 | 12,2 | 24 | 124 | 32 |
| Sells | 30 | 740 | 15,5 | 33 | 168 | 33 |
| Superior | 31 | 920 | 16,1 | 20 | 140 | 42 |
| Tucson | 32 | 750 | 16,1 | 42 | 145 | 42 |
| Wickenburg | 33 | 645 | 13,9 | 42 | 119 | 42 |

[1] Seeds were sown between 1940 and 1975. Climatic data were collected between 1931 and 1972 (Sellers & Hill, 1974).

[2] Data were unavailable but estimated from the nearest climatic station.




• A - *Sites where Lehmann lovegrass persisted and spread.*
▲ B - *Sites where Lehmann lovegrass persisted but did not spread.*
• C - *Sites where Lehmann lovegrass died.*

Figure 2 *The effect of winter temperatures and summer rainfall on the long-term persistance of Lehmann lovegrass at 33 planting sites in southeastern Arizona, USA.*

Summer rainfall exceeds 200 mm at sites 14, 16, 17, 20-22 but mean winter air temperatures are below 11° C (Figure 2, Table 2). Sites 17 and 21 are located in cold air drainage areas and winter temperature extremes are lower than at sites 1-13. Apparently, 200 mm of summer rainfall is a critical amount because plants have not spread from sown areas at sites 15, 18, 19 and 24. Failure to spread at site 23 is probably a combination of low summer rainfall and low winter temperatures.

Winter temperatures are mild at sites 25-33 (Figure 2, Table 2) and more than 60% of the annual precipitation comes in winter (Sellers & Hill, 1974). Summers are usually hot and dry and rainfall is apparently not adequate for plant survival.

## CONCLUSIONS

It is commonly believed that Lehmann lovegrass will continue to spread in the southwestern USA because it is adapted to a wide range of climatic and edaphic conditions. However, this study and others (Cox, 1984; Cox & Martin, 1984; Martin & Cox, 1984; Frasier, Woolhiser & Cox, 1984) have begun to delineate the environmental limitations of Lehmann lovegrass, and suggest that this grass is more narrowly adapted than previously thought. Climatic and edaphic conditions seem to have limited the spread of Lehmann lovegrass. In southeastern Arizona approximately 90% of the area where summer rainfall ranges between 200 and 300 mm is currently occupied by Lehmann lovegrass. Because of shallow soils and dense shrub stands the remaining areas are not likely to be invaded by Lehmann lovegrass. We suspect that Lehmann lovegrass invasion into native rangelands has been ecologically curtailed and subsequent population increases will largely be through increased stand densities, or the removal of shrub competition.

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