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Variability in germination rate among seed lots of Lehmann lovegrass

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Abstract

The regeneration success of Lehmann lovegrass (*Eragrostis lehmanniana* Nees) in southern Arizona may be partially due to rapid germination during sporadic periods of available soil moisture. There is limited information regarding germination rate of Lehmann lovegrass but it is known that total germination response for this species is highly variable. Some of this variability may result from differences in the degree of mechanical scarification during harvest, threshing, and storage. Scarified and nonscarified seed from 7 seed lots were germinated over the water potential (Ψ_W) range of 0 to -1.16 MPa. Results showed that mechanical scarification increased total germination and germination rate. Mechanical scarification reduced variability among seed lots for germination rate, but increased variability for total germination. The rapid germination hypothesis may be valid for Lehmann lovegrass as long as seed numbers are not limiting. Of the scarified seed that germinated above a Ψ_W of -0.4 MPa, at least 10% did so between days 1 and 2 of the study.

Key Words: *Eragrostis lehmanniana* Nees, mechanical scarification, reduced water potential

Lehmann lovegrass (*Eragrostis lehmanniana* Nees) has become the dominant herbaceous species in many areas of southern Arizona since its introduction from southern Africa in 1932 (Cox and Ruyle 1986, Cox et al. 1988). Tapia and Schmutz (1971) attribute some of the competitive success of Lehmann lovegrass to the rapid germination rate of its seed. Few data are available to support this hypothesis as most germination studies of Lehmann lovegrass report only total germination and not rate. There is evidence, however, that total germination of Lehmann lovegrass is highly variable among seed lots (Brauen 1967). A species-wide inference of rapid germination may be invalid if variability among seed lots is as high for germination rate as has been shown for total germination (Brauen 1967).

Lehmann lovegrass seed are dormant at harvest but seed treatments that cause physical disruption of the seed coat have been found to enhance total germination and germination rate (Brauen 1967, Haferkamp and Jordan 1977, Weaver and Jordan 1985). Variability in germination among seed lots may, therefore, result from differences in post-harvest dormancy or from differing degrees of mechanical scarification during harvest, threshing, and storage (Brauen 1967).

The first objective of this study was to determine the variability in total germination and germination rate among 7 seed lots of Lehmann lovegrass. The second objective was to determine whether mechanical scarification reduces germination variability by normalizing the degree of seed coat disruption among seed lots. Scarified and nonscarified seed were germinated at 7 different water potentials (Ψ_W) to increase the range of treatments for comparison of seed lots.

Materials and Methods

Seven seed lots of Lehmann lovegrass were obtained from various sources in southern Arizona. Lots 1 and 2 were from separate field collections made at the Santa Rita Experimental Range in 1988. Lots 3 and 4 were from field collections made by Native Plants Inc. in southeastern Arizona at an unknown date but prior to 1986. Lots 5, 6, and 7 were from field plantings at the Tucson Plant Materials Center (Soil Conservation Service) harvested in 1978, 1986, and 1989. The germination tests were conducted in August 1989.

Seeds were germinated on Spectra/Por 3 cellulose dialysis membrane (Spectrum Medical Industries, Inc., Los Angeles, Calif.)[1] in germination vials designed for control of matric potential in the seed germination environment. A germination vial consisted of a 5-cm diam by 8.5-cm high crystal snap cap vial (Thornton Plastics, Salt Lake City, Utah) containing 65 ml of either water or an osmotic solution of polyethylene glycol 8000 (PEG; Union Carbide Corp., Danbury, Conn.). A germination cup was constructed by cutting the top 2.5 cm from a 3-cm diam, clear-plastic snap-top vial. Cellulose membrane was stretched across the mouth of the vial and held in place with the snap-top lid from which a 2.5-cm diam hole had been punched. The germination cup thus formed was lowered into contact with water or osmotic solution in the larger vial. The germination cup was supported at the solution surface on a plastic screen resting on plastic rods glued to the inside of the larger vial. The cellulose membrane has a molecular weight exclusion limit of 3,500, effectively excluding PEG from contact with the seed inside the germination cup.

The PEG was mixed with water according to equation 4 of Michel (1983), as suggested by Hardegree and Emmerich (1990), to yield 7 solutions over the Ψ_W range of 0 to -1.16 MPa. The PEG solution Ψ_W was checked by measuring each solution with an SC-10 thermocouple psychrometer (Decagon Devices, Pullman, Wash.) that had been calibrated with standard salt solutions (Lang 1967).

Scarified and nonscarified seed of each seed source were germinated at each Ψ_W in a controlled-temperature room at 25 ± 1° C under both fluorescent and incandescent light for 12-hour day^{-1}. The mechanical scarification treatment followed that reported by Wright (1973) with a 0.5-ml seed sample and an 8-second scarification interval. The scarification event was replicated 8 times for each seed lot and 30 seeds from each scarification event were germinated at each Ψ_W. Eight sets of 30 nonscarified seeds from each seed source were also germinated at each Ψ_W. Germination vials were randomly arranged within 8 blocks in the controlled-temperature room. Germinated seed were counted and removed from the vials on days 1–5, 7, 9, 11, 14, 17, and 21 of the test. Germinated seed were defined as those exhibiting ≥ 2-mm radicle extension. The seeds were treated with a 50-μl fungicide suspension (Daconil; tetrachloroisophthalonitrile) immediately after being placed on the membrane surface in the germination vial.

Two indices for total germination were calculated for the seed in each germination vial: total percent germination (G), and total percent germination divided by the mean value for G at 0 MPa for the same seed source and scarification treatment (G/G_0). Two

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[1]Mention of a trademark name or proprietary product does not constitute endorsement by the USDA and does not imply its approval to the exclusion of other products that may also be suitable.

Table 1. Calculated values for Total Percent Germination (G) as a function of Ψ_W for 7 seed lots of Lehmann lovegrass both before and after mechanical scarification. Values in parentheses represent one-half of the width of calculated confidence intervals ($P \leq 0.05$).

Seed lot	Mechanical scarification	Ψ_W (MPa)						
		0	-0.11	-0.32	-0.57	-0.86	-1.00	-1.16
1	yes	55(4)	50(4)	40(3)	27(2)	13(3)	6(4)	-2(4)
2	yes	56(5)	47(4)	32(4)	17(4)	6(4)	3(4)	0(6)
3	yes	95(5)	90(4)	87(4)	85(4)	77(4)	65(4)	45(6)
4	yes	77(6)	78(5)	76(4)	68(5)	51(4)	39(4)	24(6)
5	yes	85(6)	85(6)	85(6)	84(4)	73(5)	62(4)	42(6)
6	yes	99(5)	97(4)	97(4)	97(4)	88(4)	74(4)	50(6)
7	yes	47(5)	40(4)	28(3)	16(4)	6(3)	2(3)	-1(5)
1	no	7(2)	6(1)	3(1)	1(1)	0(1)	1(1)	1(2)
2[1]	no	——	——	——	——	——	——	——
3	no	35(4)	32(4)	27(3)	20(3)	12(3)	8(4)	4(4)
4	no	12(3)	11(2)	9(2)	7(2)	4(2)	3(2)	1(3)
5	no	65(5)	60(4)	51(3)	40(3)	27(4)	21(4)	14(5)
6	no	76(7)	63(4)	47(6)	38(5)	31(5)	26(5)	15(7)
7	no	3(1)	3(1)	2(1)	2(1)	1(1)	0(1)	0(1)

[1]Nonscarified seed lot 2 had virtually no germination at any Ψ_W.

indices for germination rate were calculated for each vial: Mean days to germinate (M), and days to 10% of G (D_{10}). Cubic regression equations were calculated relating G, G/G_0, M, and D_{10} to germination solution Ψ_W for each seed source-scarification treatment. Regression equations were recalculated deleting first cubic then quadratic then linear terms that were not significant ($P \leq 0.10$). Lower order terms that were not significant were left in the equation if a higher order term was significant. Germination index values were calculated from the regression equations and model confidence intervals ($P \leq 0.05$) determined for each seed source-scarification treatment at each Ψ_W (Evans et al. 1982).

Germination rate was highly variable in treatments with a mean G/G_0 of <10% because these treatments generally had several sample replicates with zero germination and, in some cases, a single seed determined the germination rate for the entire sample. Values for D_{10} and M were, therefore, included in the regression analysis only if the mean G/G_0 for the respective treatment was ≥10%.

The data from all seed sources were aggregated to determine whether or not scarification altered germination variability among seed sources. The Ψ_W treatment replicates were averaged within seed lots, the data for all seed sources aggregated by scarification treatment, and cubic regression equations calculated relating G and M to germination solution Ψ_W. An F-ratio test was used to compare error mean square terms from the regression models for scarified and nonscarified seed. Germination index values were also calculated from the regression equations and model confidence intervals ($P \leq 0.05$) determined for each scarification treatment at each Ψ_W.

Results

Mechanical scarification increased G for all seed lots (Table 1) but also increased variability among seed lots for this germination index. Increased variability for G among scarified seed lots is indicated by the wider range of germination response at reduced Ψ_W (Table 1), and larger confidence interval widths for regression equations calculated from the aggregate data (Table 2). An F-ratio test on the regression models for the aggregate data confirmed the higher variability in G among seed lots after scarification ($P \leq 0.01$). Total germination was transformed to units of G/G_0 for the scarified seed to test whether varibility in G among seed lots was caused by inherent differences in seed viability (Table 3). This transformation did not eliminate the variability among seed lots at reduced Ψ_W but altered the relationship between seed lots in several cases (Tables 1, 3). There was some evidence of an after-ripening requirement for germination as the most recently harvested seeds (Lots 1, 2, 7) had the lowest G at all levels of Ψ_W for both the scarified and nonscarifed treatments.

Mechanical scarification lowered M (increased germination rate) for all seed lots above a Ψ_W of -1.0 MPa (Table 4). In contrast to the effect on G, scarification reduced variability among seed lots for M. This reduction in variability is indicated by the reduced range of germination response (Table 4) and smaller confidence interval widths for regression equations calculated for the aggregated data (Table 2). An F-ratio test on the regression models for the aggregated data confirmed the decrease in variability in M among seed lots after scarification ($P \leq 0.01$). The regression data also indicate that for all of the scarified treatments, at least 10% of the seed that germinated did so between days 1 and 2 of the study, down to a Ψ_W of about -0.4 MPa (Tables 2, 5). Variability in D_{10} among scarified seed lots was relatively low between a Ψ_W of 0 and about -0.4 MPa (Table 5).

All of the models for G and G/G_0 (Tables 1, 3) were significant ($P \leq 0.01$) except for nonscarified seed lot 2 which had virtually no germination at any Ψ_W. All of the models for M (Table 4) were

Table 2. Calculated values for G, G/G_0 M, and D_{10} for scarified seed and G and M for nonscarified seed as a function of Ψ_W for the aggregated data of all seed lots. Values in parentheses represent one-half of the width of calculated confidence intervals ($P \leq 0.05$).

Germination index	Mechanical scarification	Ψ_W (MPa)						
		0	-0.11	-0.32	-0.57	-0.86	-1.00	-1.16
G	yes	75(14)	70(12)	62(10)	52(8)	41(10)	35(12)	28(14)
G	no	27(9)	25(8)	21(6)	16(6)	11(7)	8(8)	5(10)
G/G_0	yes	98(12)	92(11)	80(9)	65(7)	48(9)	39(10)	30(12)
M	yes	2.8(0.5)	2.6(0.4)	2.6(0.3)	3.8(0.4)	6.3(0.4)	8.2(0.4)	10.7(0.6)
M	no	4(0.8)	4.5(0.7)	5.3(0.6)	6.4(0.5)	7.6(0.7)	8.2(0.9)	8.9(1.0)
D_{10}	yes	1.3(0.7)	1.2(0.5)	1.4(0.5)	2.2(0.6)	4.0(0.5)	5.2(0.6)	6.8(0.9)

Table 3. Calculated values of G/G_0 as a function of Ψ_W for 7 seed lots of Lehmann lovegrass after mechanical scarification. Values in parentheses represent one-half of the width of calculated confidence intervals ($P \leq 0.05$).

Seed lot	Ψ_W (MPa)						
	0	-0.11	-0.32	-0.57	-0.86	-1.00	-1.16
1	95(7)	85(6)	68(5)	46(4)	22(5)	10(6)	-4(7)
2	97(9)	81(7)	55(6)	29(8)	10(6)	4(6)	1(10)
3	98(5)	93(4)	90(5)	88(4)	79(4)	68(4)	46(6)
4	96(8)	97(6)	95(5)	85(6)	64(5)	49(5)	30(8)
5	100(7)	100(7)	100(7)	99(5)	86(5)	73(5)	49(8)
6	100(5)	98(4)	98(4)	98(4)	88(4)	75(4)	50(6)
7	95(10)	80(7)	56(7)	31(8)	11(7)	4(7)	-2(10)

Table 4. Calculated values for Mean Days to Germinate (M) as a function of Ψ_W for 7 seed lots of Lehmann lovegrass both before and after mechanical scarification. Values in parentheses represent one-half of the width of calculated confidence intervals ($P \leq 0.05$).

Seed lot	Mechanical scarification	Ψ_W (MPa)						
		0	-0.11	-0.32	-0.57	-0.86	-1.00	-1.16
1	yes	2.8(1.5)	2.5(1.0)	2.7(1.2)	4.5(1.2)	8.5(1.7)	——[1]	——
2	yes	2.6(0.9)	2.6(0.6)	3.0(0.7)	4.2(0.8)	6.4(1.2)	——	——
3	yes	2.6(0.7)	2.9(0.5)	3.0(0.6)	3.2(0.5)	4.9(0.5)	7.0(0.5)	10.7(0.7)
4	yes	3.6(0.7)	3.2(0.5)	3.3(0.5)	4.4(0.6)	7.2(0.5)	9.2(0.5)	11.9(0.7)
5	yes	2.7(0.7)	2.6(0.6)	2.4(0.5)	3.4(0.5)	6.0(0.4)	7.9(0.4)	10.4(0.6)
6	yes	2.4(0.9)	2.0(0.7)	1.8(0.6)	2.8(0.8)	5.5(0.6)	7.5(0.6)	10.2(1.0)
7	yes	2.4(0.3)	2.6(0.3)	2.9(0.2)	3.4(0.4)	——	——	——
1	no	5.5(1.5)	5.5(1.5)	5.5(1.5)	5.5(1.5)	——	——	——
2[2]	no	——	——	——	——	——	——	——
3	no	3.6(1.3)	4.1(1.2)	4.9(0.9)	6.1(0.8)	7.3(1.0)	7.9(1.2)	8.6(1.5)
4	no	5.0(1.6)	5.6(1.3)	6.9(1.1)	8.4(1.2)	10.2(1.8)	11.1(2.1)	——
5	no	3.8(0.6)	4.3(0.5)	5.1(0.4)	6.0(0.3)	7.1(0.4)	7.7(0.5)	8.3(0.6)
6	no	3.2(0.7)	3.3(0.5)	3.3(0.6)	3.6(0.5)	5.1(0.6)	6.8(0.5)	9.7(0.8)
7	no	4.6(1.6)	4.6(1.6)	4.6(1.6)	4.6(1.6)	——	——	——

[1]Treatments with a measured mean value of $G/G_0 < 10$ were not included in the regression model.
[2]Nonscarified seed lot 2 had virtually no germination at any Ψ_W.

Table 5. Calculated values for Days to 10% of G (D_{10}) as a function of Ψ_W for 7 seed lots of Lehmann lovegrass after mechanical scarification. Values in parentheses represent one-half of the width of calculated confidence intervals ($P \leq 0.05$).

Seed lot	Ψ_W (MPa)						
	0	-0.11	-0.32	-0.57	-0.86	-1.00	-1.16
1	1.4(1.5)	1.1(1.0)	1.2(1.2)	3.0(1.3)	7.1(1.8)	——[1]	——
2	1.4(1.2)	1.1(0.8)	1.3(1.0)	3.0(1.1)	6.7(1.9)	——	——
3	1.1(0.5)	1.2(0.4)	1.3(0.4)	1.6(0.4)	2.8(0.4)	4.0(0.4)	6.0(0.5)
4	1.8(1.1)	1.3(0.8)	1.1(0.8)	2.0(0.9)	4.7(0.8)	6.8(0.8)	9.7(1.2)
5	1.2(0.4)	1.2(0.4)	1.3(0.4)	1.6(0.3)	3.0(0.3)	4.4(0.3)	6.6(0.4)
6	1.1(0.4)	1.1(0.3)	1.1(0.3)	1.3(0.3)	2.4(0.3)	3.5(0.3)	5.3(0.4)
7	1.2(0.3)	1.4(0.3)	1.5(0.3)	2.8(0.3)	——	——	——

[1]Treatments with a measured mean value of $G/G_0 < 10$ were not included in the regression model.

significant ($P \leq 0.01$) except for nonscarified seed lot 2, which had close to zero germination and nonscarified seed lots 1 and 7 for which there were no significant regression coefficients. The calculated germination indices in Table 4 for nonscarified seed lots 1 and 7, therefore, represent the mean value of M for those treatments with a $G/G_0 > 10\%$. All of the models for D_{10} (Table 5) and all of the aggregated data models (Table 2) were significant ($P \leq 0.01$).

Discussion

Lehmann lovegrass seeds have been tested for germination response to temperature (Martin and Cox 1984, Knipe 1967, Jordan and Haferkamp 1989), water stress (Knipe and Herbel 1960, Tapia and Schmutz 1971), specific ions (Ryan et al. 1975b), soil texture and planting depth (Cox and Martin 1984), wet-dry sequences (Wilhem 1969, Frasier 1989), and pH (Ryan et al. 1975a). In all of these studies a single seed source was used and for most, only total germination was measured. The evidence from Brauen (1967) and our data (Table 1) show high variability among seed lots for total germination of both scarified and nonscarified seed. This variability brings into question the validity of inferences made in previous studies that compared total germination of a single seed lot of Lehmann lovegrass to that of other species.

Variability in total germination among nonscarified seed lots may have resulted from inherent differences in seed viability, after-

ripening dormancy (Wright 1973), or the degree to which scarification occurred during harvest, threshing, and storage. Scarification and re-expression of G as a percent of G_0 did not eliminate differences among seed lots (Table 3), suggesting that other factors contribute to variability in total germination.

Weaver and Jordan (1985) found that pregermination heat treatment increased the germination rate of Lehmann lovegrass at $\Psi_W = 0$. Our study shows that mechanical scarification has the same effect down to a Ψ_W of about -1.0 MPa. In contrast to the effect on total germination, scarification was found to reduce the variability among seed lots for germination rate (Tables 2, 4). In future studies it may, therefore, be possible to define the germination rate response of scarified Lehmann lovegrass seed with relatively little seed lot replication.

The importance of germination rate to the regeneration success of Lehmann lovegrass can be expressed in 2 ways. In the simplest case, rapid germination increases the likelihood that a seedling can establish a root system before moisture evaporates from the surface horizon (Weaver and Jordan 1985, Jordan 1983). Rapid germination would be a disadvantage, however, if all seed germinated during the first summer rain, and then died from lack of subsequent soil moisture (Frasier 1989). The simple case for rapid germination can be modified if we accept the hypothesis that variability in seed dormancy characteristics insures that some seed are germinable at any given time during the growing season (Brauen 1967). Laboratory germination of Lehmann lovegrass is enhanced by mechanical and chemical scarification, moist prechilling, and various sequences of wetting, drying, and heat application (Wright 1973, Haferkamp and Jordan 1977). It is probable that natural scarification in the field maintains a subpopulation of nondormant seed that is ready to germinate during any given precipitation event. We do not, therefore, recommend that mechanical scarification be used as a presowing seed treatment unless supplemental water is available during the establishment period. As Lehmann lovegrass is a prolific seed producer, we also suggest that the only relevant germination index for comparing Lehmann lovegrass to other species is germination rate. D_{10} may be a more useful rate index than M for this species because D_{10} indicates the germination rate of the most rapidly germinating subpopulation of seed. The regression data for D_{10} (Tables 2, 5) indicate that this subpopulation has a germination rate of between 1 and 2 days down to a Ψ_W of about -0.4 MPa. Therefore, the rapid germination hypothesis of Tapia and Schmutz (1971) is probably valid as long as seed numbers are not limiting.

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