Jl S. Afr. Bot. 50 (2): 159–170 (1984)

TEMPERATURE, TIMING OF PRECIPITATION AND SOIL TEXTURE EFFECTS ON GERMINATION, EMERGENCE AND SEEDLING SURVIVAL OF SOUTH AFRICAN LOVEGRASSES

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ABSTRACT

The germination, emergence and seedling survival of three South African lovegrasses and a genetically selected accession from parents originally collected in South Africa were evaluated at different temperatures, under different initial precipitation regimes and in three soils common to the south western U.S.A. Boer lovegrass (*Eragrostis curvula* var. *conferta* Nees) accession Catalina was genetically selected from boer lovegrass accession A–84; which was collected in South Africa. Catalina seed germinated over a wider range of temperatures, from greater depths in the three tested soils and seedlings were more drought tolerant than were those of Lehmann (*Eragrostis lehmanniana* Nees), Atherstone (*Eragrostis atherstonei* Stapf.) or boer lovegrass A–84.

UITTREKSEL

DIE INVLOED VAN TEMPERATUUR, FREKWENSIE VAN WATERTOEDIENING EN GRONDTEKSTUUR OP DIE ONTKIEMING, VERSKYNING EN SAAILINGOORLEWING VAN SUID-AFRIKAANSE OULANDSGRASSE

Die ontkieming, verskyning en saailingoorlewing van drie Suid-Afrikaanse oulandsgrasse en 'n geneties geselekteerde aanwins van ouers wat oorspronklik in Suid-Afrika versamel is, is onder verskeie temperature, neerslag en drie grondsoorte wat algemeen in die suid-westelike V.S.A. voorkom, ge-evalueer. Boer-oulandsgras (*Eragrostis curvula* var. *conferta* Nees) aanwins Catalina is geneties geselekteer van boer-oulandsgras aanwins A–84, wat in Suid-Afrika versamel is. Catalina-saad het oor 'n wyer verskeidenheid temperature, vanuit die groter diepte in drie getoetste grondsoorte ontkiem en saailinge was meer droogtebestand as dié van Lehmann (*Eragrostis lehmanniana* Nees), Atherstone (*Eragrostis atherstonei* Stapf.) of Boer-oulandsgrasse A–84.

Key words: *Eragrostis*, lovegrass, south western U.S.A., germination, seedling survival, drought tolerance.

INTRODUCTION

More than 250 accessions of 80 grass species have been seeded at 400 non-irrigated locations in the south western U.S.A. and northern Mexico in the

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Accepted for publication 30th September, 1983.

past 92 years (Cox *et al.*, 1982). The most easily established and persistent grasses were either lovegrasses introduced from South Africa or genetic lines selected from South African grasses.

Lehmann lovegrass (*Eragrostis lehmanniana* Nees) accession 68 (A–68) and boer lovegrass (*Eragrostis curvula* var. *conferta* Nees) accession 84 (A–84) were introduced into the U.S.A. in mid-1930 (Cox *et al.*, 1982). Atherstone lovegrass (*Eragrostis atherstonei* Stapf.) accession 16753 was introduced in 1961 (Holzworth, 1980). Atherstone has been taxonomically re-identified as a hybrid cross between *Eragrostis lehmanniana* Nees and *Eragrostis trichophera* Coss & Dur. (Terrell, 1977) and renamed as Cochise lovegrass (Holzworth, 1980). Cochise lovegrass is generally easier to establish, more productive and persists longer than A–68 Lehmann lovegrass (Jordan, 1981).

Wright (1971) tested 16 boer lovegrass accessions for seedling drought tolerance under controlled environmental conditions. Only 216 of 50,000 seedlings survived. Seed was harvested from the interpollinating surviving plants in isolation and seedling drought tolerance was retested. Line 3–17 was superior in seedling drought tolerance and was named as Catalina boer lovegrass. Catalina traces to PI–203347 and A–84 boer lovegrass. Catalina was field tested in the semi-arid south western U.S.A. (Herbel *et al.*, 1973) and released in 1969 (Wright, 1971). Catalina seedlings in the field appear to be more drought tolerant than A–84 seedlings (Wright and Jordan, 1970) but mature plants are smaller and produce less forage than A–84 (Cox and Jordan, 1983).

Grass establishment from seed requires a viable seed and favourable temperature, precipitation and soil for germination and seedling development. Seeds often germinate but seedlings fail to survive because (1) temperatures are not within the tolerable range, (2) precipitation distribution and amounts are inadequate and (3) the root may not be capable of penetrating the soil.

Soil temperature and available soil water are often maximised in summer, and reseeding is conducted prior to warm season precipitation in non-irrigated arid and semi-arid regions of the world (Cox *et al.*, 1982; Silcock and Williams, 1976; Field-Dogdson, 1976). Soil water used in seed germination, emergence and seedling growth is replenished by precipitation and depleted by evapo-transpiration. Precipitation events in summer are intermittent, with rainfall periods being much shorter than dry periods. Therefore, soils near the surface, where seed are planted, often dry so rapidly after seed germination that the seedlings die. The identification of species or accessions which will germinate at temperatures when soil moisture is available but evapo-transpiration is not limiting might increase the probability of seedling establishment. Such species might be seeded in fall, winter or spring.

One might hypothesise that if the first wet period is short, the seed may not germinate but might emerge after the next wet sequence (Watt, 1982). If the first sequence is adequate for germination of most or all of the seeds but is followed by a long drought, a "false start" would occur (Young *et al.*, 1970) and the seedlings would die. If the first wet sequence is adequate for seedlings to develop to a stage that can survive a drought-induced dormancy, a high percentage of the seedlings might survive a long drought (Wilson and Briske, 1979).

Germination and seedling emergence are direct responses to temperature and water availability. However, recent field observations have indicated that lovegrass emergence is also influenced by soil texture and planting depth. Currently recommended seeding depths for lovegrasses in the U.S.A. are 5 to 7 mm (Jordan, 1981), but the effects of interactions between seeding depths and soil texture on accession emergence have not been investigated.

Determining the response of lovegrass accessions to: (1) a temperature range, (2) several wet, dry, and rewet-day sequences and (3) soils with differing physical characteristics should make it possible to characterise germination, emergence and seedling survival requirements. These characteristics can then be used to correlate specific accessions with seasonal planting dates, precipitation probabilities and soils, and reduce some risks associated with rangeland seeding.

This paper describes results obtained in laboratory and greenhouse experiments designed to determine the effects of: (1) constant temperatures on germination; (2) selected wet-day, dry-day and rewet-day sequences on emergence and seedling survival and (3) soil texture on emergence of three South African grasses and one accession selected in the United States from boer lovegrasses originally introduced from South Africa. The research was conducted at Tucson, Arizona, U.S.A.

MATERIAL AND METHODS

Germination at constant temperatures

Fifty seeds of A–68, Cochise, A–84 and Catalina lovegrasses were sown on Whatman #3 filter paper and placed in plastic petri dishes. Approximately 7 to 9 mℓ of distilled water were added and seed were germinated at either 15, 18, 21, 24, 27 or 29 C on a thermogradient plate (Larsen, 1962) under alternating 15 h light and 9 h dark. Germination was considered complete when the seed radical was 15 mm in length. Germinated seeds were counted at 6 and 12 days after the addition of water.

Experimental design was a stratified randomised block because temperature was constant across the plate. There were six temperatures, one petri dish for each accession randomised within each temperature and the experiment was repeated six times (blocks). Accession germination means were compared across temperatures for each observation date by analysis of variance. When F values indicated significant main effects or interactions, a Duncan's New Multiple Range Test (Steel and Torrie, 1960) was used to separate means ($P \leq 0,05$).

Emergence, seedling survival and timing of precipitation

Cotton was placed in the bottom of 38 × 200 mm, tapered plastic cones. Each cone was filled with 210 g of dry 60 mesh silica sand to provide a uniform growth medium and eliminate undesirable seed contamination. Ten seeds of either A–68, Cochise, A–84 or Catalina lovegrasses were sown on the medium surface and covered with 2 to 3 mm of dry silica sand.

Water was applied with an overhead reciprocating spray boom sprinkling system (Frasier *et al.*, 1984). All cones initially received a 20 g water application or approximately 10 % water content by medium weight. Subsequent applications were adjusted and sufficient water added to return the cone water content to 10 % of the medium weight.

Water application was in predetermined wet-dry-wet sequences of either 1, 2 or 3 wet days, 7 dry days and 4 rewet days. All cones were watered at the beginning of the experiment, but due to the length of the wet day sequences the seven dry days ended on days 8, 9 and 10, and the four rewet days on 12, 13 and 14. Cone groups in dry day sequences were covered with 18-gauge galvanised sheet metal "splash roofs" when cone groups in wet day sequences were watered.

Emergence was complete when the first seedling leaf was 15 mm above the growth media surface and seedlings were counted daily. Peak emergence occurred on days 3 and 4, and varied between accessions and water rates. The end of the seven dry days represents peak seedling mortality and the end of the four rewet days represents seedlings which survived the seven dry days plus new seedlings.

Experimental design was a completely randomised block with six blocks. Each block included the three wet-day sequences, and five replicated and randomly distributed cones of each lovegrass. Block means were considered as replications. Means were compared across the three wet day sequences by analysis of variance at the following dates: (1) day 3, (2) day 4, (3) at the end of the seven dry days and (4) at the end of the four rewet days. When F values were significant ($P \leq 0,05$), a Duncan's New Multiple Range Test (Steel and Torrie, 1960) was used to separate means.

Emergence as influenced by soil texture and planting depth

Soils with textural characteristics common to arid and semi-arid regions of the south western U.S.A. and northern Mexico were collected in summer 1982. Pima silty clay loam soils were collected in the Santa Cruz flood plain 10 km south of Tucson, Arizona; Sonoita silty clay loam was collected in a creosotebush [*Larrea tridentata* (DC.) Cov.] stand 45 km south of Tucson and Comoro sandy loam was collected in a velvet mesquite [*Prosopis juliflora* var. *velutina* (Woot.) Sarg.] stand 47 km south east of Tucson. All soils were sampled from 0 to 150 mm depths. The three soils are classified as thermic Typic Torrifluvents or thermic typic Haplargids (Gelderman, 1972). Clay content of both the Pima and Sonoita silty clay loam soils was 20%; however, the clay fraction of the Pima was 60% montmorillonite and the Sonoita was 80% kaolinite.

Soils were screened to 5 mm and thoroughly mixed. Soils were added to 150 × 150 mm tapered plastic pots; to 127, 122, 117, 112 and 107 mm depths above the pot base. Twenty-five pure live seed (P.L.S.) of one lovegrass accession were sown on the soil surface of each pot. Soils were added to 127 mm depths in all pots. Thus, seed were planted at 0, 5, 10, 15 and 20 mm depths.

Pots were subirrigated with distilled water to ensure that the soil surfaces were moist and undisturbed during the 14-day study. Emergence was considered complete when the first leaf was 15 mm above the soil surface in those pots where seed were planted at 5 to 20 mm depths, or when the first leaf was 15 mm above the soil surface and the seed radical had penetrated the soil in those pots in which seed were sown on the surface. Seedlings were counted daily.

Experimental design was a completely randomised block with six blocks. Each block contained 60 pots; four accessions, three soils and five planting depths. Since some accessions did not emerge from the 5 to 20 mm depths in some soils, analysis of variance was applied to each planting depth. Only one accession emerged from 10 to 20 mm depths in the Pima silty clay loam so data were subjected to analysis of variance with unequal sample numbers. When F values indicated significant main effects or interactions, a Duncan's New Multiple Range Test (Steel and Torrie, 1960) was used to separate means ($P \leq 0{,}05$).

RESULTS AND DISCUSSION

Germination at constant temperatures

Lovegrass germination generally increased as temperature increased from 15 to 27 C, and was similar at 27 and 29 C after 6 days (Table 1).Germination of Catalina seed was greatest across all temperatures followed by

Cochise and A–84 with A–68 having the least. Germination of Catalina and Cochise seed was similar at 15 C, but germination of Catalina seed increased to 63 % at 18 C while germination of Cochise seed remained essentially unchanged. A–68 and A–84 seeds emerged when the temperature approached 21 C.

Lovegrass seed germination increased as temperature increased from 15 to 21 C, but was similar at 24 to 29 C after 12 days (Table 2). Catalina seed germination varied from 72 to 96 %, was greatest at 18 C and peak germination occurred at 9 to 12 degrees lower than with the remaining accessions.

TABLE 1

Mean[1] germination (%) of four lovegrass accessions at six constant temperatures (C) after six days.

Accession	Temperature 15	18	21	24	27	29	Accession[2] Mean
A-68	0	0	3	34	45	33	19,2^{d}
Cochise	18	17	55	67	72	64	48,8^{b}
A-84	0	0	8	28	65	77	29,7^{c}
Catalina	19	63	81	81	84	87	69,2^{a}
Temperature Mean[3]	9,2^{e}	20,0^{d}	36,7^{c}	52,5^{b}	66,5^{a}	65,2^{a}	

[1] Each mean is the average of six replications of 50 seed
[2] Accession means followed by the same superscript are not different ($P \leq 0{,}05$)
[3] Temperature means followed by the same superscript are not different ($P \leq 0{,}05$)

TABLE 2.

Mean[1] germination (%) of four lovegrass accessions at six constant temperatures (C) after twelve days.

Accession	Temperature 15	18	21	24	27	29	Accession[2] Mean
A-68	15	28	66	74	84	77	57,3^{c}
Cochise	50	51	79	79	79	68	67,7^{b}
A-84	2	13	44	54	72	85	45,0^{c}
Catalina	72	96	87	87	87	88	86,2^{a}
Temperature Mean[3]	34,7^{d}	47,0^{c}	69,0^{b}	73,5^{ab}	80,5^{a}	79,5^{a}	

[1] Each mean is the average of six replications of 50 seed
[2] Accession means followed by the same superscript are not different ($P \leq 0{,}05$)
[3] Temperature means followed by the same superscript are not different ($P \leq 0{,}05$)

The rapid and consistently high Catalina seed germination suggests that this accession is adapted over a greater temperature gradient and could be seeded and expected to germinate following warm or cool season moisture in warm temperate regions. Germination of Cochise and A–68 seeds was greatest at 27 C and inhibited at 29 C. Thus, these accessions should be seeded at higher elevations in spring or fall where temperatures are moderate. Germination of A–84 increased with increasing temperature and seeding should be limited to regions where summers are hot and moist.

Emergence, seedling survival and timing of precipitation

Catalina and Cochise seedling emergence occurred 2 days after the initial water applications on the three wet day sequences (Table 3). Catalina and Cochise seedling emergence increased rapidly between days 2 and 3 before either A–68 or A–84 had emerged. Cochise seedling emergence was similar on both 1 and 2 wet-day sequences but approximately 50 % greater on the 3 wet-day sequence. Catalina seedling emergence was similar to Cochise on the 1 wet-day sequence, 50 % greater on the 2 wet-day sequence and seedling emergence was similar on the 3 wet-day sequence.

Initial peak densities occurred on day 4 and either 1, 2 or 3 days after the

TABLE 3

Emergence (%) of four lovegrass accessions following either one, two or three wet-days, seven dry-days and four wet-days.

Accession	Days Wet	Days after initial wet day			
		3*	4	End Seven Dry-Days	End Four Wet-Days
A–68	1	0^{c}	0^{f}	0^{c}	10^{d}
	2	0^{c}	0^{f}	0^{c}	8^{d}
	3	0^{c}	4^{de}	0^{c}	10^{d}
Cochise	1	17^{b}	25^{c}	22^{b}	43^{b}
	2	17^{b}	52^{b}	47^{b}	51^{ab}
	3	40^{a}	52^{b}	48^{b}	55^{a}
A–84	1	0^{c}	0^{f}	0^{c}	21^{c}
	2	0^{c}	1^{e}	0^{c}	27^{c}
	3	0^{c}	8^{d}	0^{c}	21^{c}
Catalina	1	19^{b}	21^{c}	18^{c}	47^{ab}
	2	40^{a}	56^{a}	51^{a}	58^{a}
	3	40^{a}	56^{a}	51^{a}	59^{a}

*Means in columns followed by the same superscripts are not different ($P \leq 0,05$)

initial water application (Table 3). A–68 and A–84 seedlings began to emerge on the 3 wet-day sequence and those of A–84 on the 2 wet-day sequence. More than 50 % of the Catalina and Cochise seed produced seedlings on the 2 and 3 wet-day sequences, whereas half that number were present on the 1 wet-day sequence.

No A–68 or A–84 seedlings survived following the 7 dry days (Table 3), but seedlings of both emerged during the 4 rewetting days. Catalina seedling mortality was less than Cochise, differences ($P \leq 0,05$) were significant at the 2 and 3 wet-day sequences, but not at the 1 wet-day sequence. However, both Catalina and Cochise seedlings exhibited similar seedling drought tolerant characteristics.

Catalina and Cochise seedling emergence after the final 4 rewet days varied from 8 to 9 % on the 2 and 3 wet-day sequences (Table 3). Catalina seedling emergence increased to 62 % and the emergence of Cochise increased to 40 % on the 1 wet-day sequence which indicates that seed which were moist for only a short time are viable and may germinate when soil water conditions improve.

Jordan (1968; 1969; 1970; 1971 and 1972) sowed these four lovegrass accessions in spring and summer, measured daily precipitation and recorded seeding survival at the end of the summer growing period at three sites and over five years in Arizona, U.S.A. Seedlings emerged but failed to survive in 13 of the 15 planting years. Cox and Jordan (1983) documented the short- and long-term lovegrass density and production changes in two planting years where adult plants had persisted for more than 10 years. Precipitation events began in late summer in both planting years, there were two to three consecutive precipitation events which deposited more than 50 mm, and following storms occurred at 4 to 14 day intervals for 30 to 40 days.

Emergence as influenced by soil texture and planting depths

Germination of the lovegrass accessions on surface soils averaged 23 or 24 seed/pot. A–68 and A–84 seedling radicals grew horizontally, fewer than 28 % penetrated the soil surfaces of the Pima and Sonoita silty clay loams, and those which did not penetrate the surface died within 48 h.

Catalina seedling emergence was greatest, Cochise intermediate, and A–68 and A–84 were least, across all soils when seed were sown on the soil surfaces (Table 4). Lovegrass emergence was similar on Sonoita and Comoro soils, but fewer seedlings emerged from Pima which contained the expanding clay fraction.

A–68 seedlings failed to emerge when seeds were planted below the surface in the three soils (Table 4). Emergence of Catalina seedlings was 50 % more than A–84 and Cochise across the three soils at 5 mm depths. Acces-

TABLE 4

Mean[1] emergence of four lovegrass accessions sown at five depths in three soils.

Depth (mm)	Accession	Soil			Accession[2] Mean
		Pima Silty Clay Loam	Sonoita Silty Clay Loam	Comoro Sandy Loam	
0	A-68	4	6	8	6,0^c
	Cochise	7	13	16	12,3^b
	A-84	1	7	11	6,3^c
	Catalina	13	20	20	17,7^a
	Soil Mean[3]	6,2^b	11,5^a	13,7^a	
5	A-68	0	0	0	0,0^c
	Cochise	5	5	4	4,7^b
	A-84	2	6	7	5,0^b
	Catalina	5	15	15	11,7^a
	Soil Mean	3,0^b	6,5^a	6,5^a	
10	A-68	0	0	0	0,0^c
	Cochise	0	3	5	2,7^b
	A-84	0	4	5	3,0^b
	Catalina	5	7	11	7,7^a
	Soil Mean	1,2^c	3,5^b	5,2^a	
15	A-68	0	0	0	0,0^c
	Cochise	0	4	4	2,7^b
	A-84	0	0	0	0,0^c
	Catalina	2	8	12	7,3^a
	Soil Mean	0,5^b	3,0^a	4,0^a	
20	A-68	0	0	0	0,0^c
	Cochise	0	3	3	2,0^b
	A-84	0	0	0	0,0^c
	Catalina	2	8	8	6,0^a
	Soil Mean	0,5^b	2,7^a	2,7^a	

[1] Each mean is the average of six replications of 25 P.L.S.

[2] Accession means by depth, within column followed by the same superscripts are not different ($P \leq 0,05$)

[3] Soil means, within a row followed by the same superscripts are not different ($P \leq 0,05$)

sion emergence was similar for the sandy loam and the Sonoita silty clay loam, and inhibited in silty clay loam soils with expanding clay.

Cochise and A-84 seedlings failed to emerge from the Pima silty clay loam when planted at 10 mm and greater depths (Table 4). Only Catalina seedlings emerged from the Pima soil when seeds were planted at 15 and 20 mm depths. Catalina seedling emergence was significantly ($P \leq 0,05$) more than Cochise on Pima soils. However, there were no differences ($P \leq 0,05$) in average lovegrass emergence in these soils.

Catalina boer lovegrass emergence was greater from all depths (0 to 20 mm) as compared to the other lovegrasses (Table 4). Greater emergence can be expected from surface sown seeds; however, the soil surface dries rapidly in summer and it is desirable to plant seed below the surface where moisture persists longer (Tadmore and Cohen, 1968). The majority of A–68 and A–84 seed radicals failed to penetrate the soil surfaces when surface sown. The greater number of Catalina and Cochise seedlings emerging from greater depths suggests that a greater portion of seed reserves may be initially allocated for shoot growth, even though seed sizes of the respective grasses are similar (Jordan, 1981).

The presence of an expanding clay fraction reduced lovegrass emergence from the surface and 5 mm depths and inhibited emergence from 10 to 20 mm depths; with the exception of Catalina boer lovegrass (Table 4). Lovegrass seedling emergence, of those accessions which did emerge, was similar in non-expanding silty clay loam and sandy loam soils, with the exception of seeds planted at 10 mm.

The number of Catalina seedlings emerging from all soils and depths, and the number of Cochise seedlings emerging from non-expanding silty clay loam and sandy loam soils at all depths indicates that these grasses have a greater emergence potential as compared to A–68 and A–84. Expanding silty clay loams are often, but not always, found in alluvial plains while sandy loams are usually found near mountainous or foothill areas in the south western U.S.A. Summer storm numbers and intensities usually decrease with decreasing elevation (Jordan, 1981). Therefore, seeding failures are assumed to be associated with the lack of precipitation and proper emphasis has not been given to soil texture, clay fractions and planting depths.

CONCLUSIONS

These results demonstrate the importance of temperature, timing of precipitation and soil texture on the germination, emergence and seedling survival of four lovegrasses. The more important findings show that: (1) A–68 Lehmann lovegrass and A–84 boer lovegrass germination is inhibited by cool temperatures, emergence is slow, seedlings are not drought tolerant and both must be planted near the soil surface which dries rapidly in summer and (2) Catalina boer lovegrass and Cochise lovegrass germinate at cooler temperatures, emerge quickly, seedlings are drought tolerant and both may be planted at greater depths than A–68 and A–84. However, Catalina is generally superior to Cochise.

Catalina was developed in the U.S.A. from boer lovegrass collections made in South Africa (Wright, 1971). Catalina germination and seedling characteristics suggest that this accession will establish on a greater variety of sites in arid and semi-arid regions of the world; as compared to A–68, A–84 and Cochise lovegrasses.

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