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Moisture and Temperature Effects on Emergence and Initial Growth of Two Range Grasses[1]

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ABSTRACT

This research, conducted in controlled light-temperature chambers, studied the effects of two temperature regimes and five moisture levels on early growth of black grama (*Bouteloua eriopoda* (Torr.) Torr.) and boer lovegrass (*Eragrostis chloromelas* Steud.). The maximum daily soil temperatures ranged from 53 to 67C in the high temperature regime, and from 38 to 51 C in the low temperature regime, depending on moisture level. The daily minimum temperatures were about 25C in all treatments. The five soil moisture levels were determined as a portion of the volume required to maintain field capacity conditions. Level A was approximately field capacity; levels B and C were watered as level A on the planting day, and then reduced to about a half and a third of level A for the remainder of the 21-day trial. Levels D and E were watered as level A for the first 3 days, and then reduced to about a half and a third of level A for the remainder of the trial.

In the high temperature regime black grama did not emerge at moisture levels B and C; and boer lovegrass did not emerge at levels B, C, and E. In addition, boer lovegrass did not emerge in the low temperature regime at moisture level C. Survival of emerging seedlings ranged from 0 to 4.7% in the high temperature regime at all moisture levels except A. Reduced soil moisture, a day after planting, was more detrimental to survival than reducing soil moisture the third day after planting. Survival of black grama at moisture level A in the high temperature regime was not adversely affected by the high leaf temperatures (81C). The shoot lengths and weights of surviving black grama seedlings were always greater than those of boer lovegrass. Survival and growth of seeded species in the Southwest would be enhanced if soil temperatures and evaporation from the soil surface were reduced. Under the conditions of this 21-day trial it took about 70 mm of water for either species to survive in the low temperature regime and about 231 mm to survive in the high temperature regime.

***Additional index words:* *Bouteloua eriopoda, Eragrostis chloromelas,* Soil moisture tension, Survival.**

SEEDING Southwestern ranges depleted by drought, overgrazing, and brush invasion has become a necessity if a measure of the former productivity is to be regained. Moisture at the seedling depth is often in short supply (C. H. Herbel, 1964. Annual report. 105 p.). This study was designed to determine the effects of two temperature regimes and five moisture levels on seedling emergence and initial growth of black grama (*Bouteloua eriopoda* (Torr.) Torr.) and boer lovegrass (*Eragrostis chloromelas* Steud.).

McGinnies (1960), using six cool-season range grasses, studied the effect of moisture and temperature on germination. As moisture stress increased germination was delayed, the rate of germination was reduced, and total germination after 28 days was lower. Higher germination percentages were obtained under high moisture stress at 20C than at 10 or 30C.

Tadmor and Hillel (1964) used two methods in studying the effects of moisture relations in germination: *(1)* germination of seed at constant temperature conditions (21C) in osmotic solutions; and *(2)* germination at constant temperature in soil samples with controlled moisture stress. They concluded that all osmotic concentrations up to 1.0 bar did not affect the onset of germination but slightly decreased the final germination percentage. As the osmotic concentrations increased from 1.0 to 15.0 bars, the onset of germination was delayed. The optimum temperature for germination of the four species studied was 16 to 21C (Tadmor and Hillel, 1965). They concluded that maximum germination required moisture conditions near field capacity. A moisture content of two-thirds to three-fourths field capacity, severely reduced germination; at 15 bars it was zero.

Knipe and Herbel (1960) tested the effects of limited moisture on germination and initial growth of six grass species. They concluded that with the exception of lehmann lovegrass (*Eragrostis lehmanniana* Nees), the time required for germination was not greatly increased by increasing osmotic concentration from 0.3 to 7.0 bars. Final germination percentages, however, were significantly reduced in lehmann lovegrass,

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boer lovegrass, and mesa dropseed (*Sporobolus flexuosus* (Thurb.) Rydb.) by increasing osmotic concentrations from 0.3 to 7.0 bars. Also, the growth of the seedlings decreased significantly by the same increase in osmotic concentrations. When subjected to 15.0 and 20.0 bars, black grama and bush muhly (*Muhlenbergia porteri* Scribn.) germinated surprisingly well but did not develop measurable seedlings.

Glendening (1942) reported on a study conducted at the Santa Rita Experimental Range concerning germination and seedling emergence in relation to soil moisture conditions. He found that moisture content of the soil was consistently greater under a straw or gauze cover than that of bare soil. Straw litter was the best treatment studied for improving soil moisture conditions. It increased germination and emergence 4 to 20 times over that which occurred under conditions of bare soil.

MATERIALS AND METHODS

This study was conducted in a light chamber supplemented with infrared bulbs to obtain desired temperatures. The light characteristics, daily light cycle, general seeding procedures, methods of measuring soil moisture and temperature, details of plant measurement, and methods of statistical analysis have been presented in a previous paper (Sosebee and Herbel, 1969). The seeds were planted (50 per dish) at the 13-mm depth in sterilized loamy sand contained in plastic dishes, 10 × 10 × 10 cm.

The experimental design was a randomized complete block with a split plot analysis. The analysis consisted of three replications and two soil temperature treatments (whole plot units), and five soil moisture treatments and two species treatments (subplot units). The replications were with time and were terminated on the 21st day after planting.

The five soil moisture levels were determined as a portion of the volume of water required to maintain field capacity conditions. Treatment A was watered to approximate field capacity each day. Treatments B and C were watered to approximate field capacity the day of planting and thereafter were watered as shown in Table 1. Treatments D and E were watered to approximate field capacity the first 3 days and then watered as indicated in Table 1. Table 1 shows the amount of water applied to each treatment. During the 21-day trial, levels A through E in the high temperature regime received a total of 231, 143, 82, 153, and 97 mm of water, respectively. In the low temperature regime it was 150, 78, 61, 86, and 72 mm, respectively. Although the low temperature regime received less water per treatment than the high temperature regime, they had approximately the same soil moisture condition during the night since the containers were watered at 5:00 PM. Although treatment C was not as wet each morning as the four other treatments, the soil moisture tension at the 13-mm depth was only 0.3 bar. The moisture tension three times during the day from the 4th through the 20th day is shown in Table 2.

The soil temperature was measured three times a day, 8:00 AM, 1:00 PM, and 4:00 PM. Soil temperatures for various treatments are shown in Table 3.

The leaf temperatures of the seedlings were measured only once, at the end of a 20-day experimental period. These measurements were taken at 12:00 M, the hottest period of the diurnal cycle. They were measured with a thermocouple constructed of copper and chromel wires.

RESULTS

Emergence was computed as a percentage of the germination from standard tests. There was a significant moisture × species × temperature interaction, indicating the three attributes were not independent of each other. Table 4 shows the significant differences obtained in emergence under the different moisture and temperature regimes. There was no emergence of black grama or boer lovegrass in the high temperature regime at moisture levels B and C. Boer lovegrass also failed to emerge at moisture level E in the high temperature regime and at moisture level C in the low temperature regime. Boer lovegrass had a slightly higher emergence than indicated from germination tests in levels A and D in the low temperature regime. This indicates that these environmental conditions are more favorable for emergence. Emergence of black grama was not delayed by the high temperature regime in the moisture levels which had seedling emergence. However, the high temperatures did delay emergence of boer lovegrass in moisture level A about 4 days.

The analysis on survival data of black grama and boer lovegrass showed a significant moisture × species × temperature interaction. Table 5 shows the survival as a percentage of emergence. In the high temperature regime there was little or no survival of both species under all moisture levels except A. Within the low temperature regime, there was significantly

Table 1. Daily watering of five moisture treatments within two soil temperature regimes.

Treatment	Water added, mm, on day:				Water added, mm, on day:			
	1	2	3	4-20	1	2	3	4-20
	High temp regime				Low temp regime			
A	19.6	9.7	11.2	11.2	9.7	7.4	7.4	7.4
B	19.6	4.8	6.6	6.6	9.7	3.6	3.6	3.6
C	19.6	2.5	3.3	3.3	9.7	2.0	1.8	2.8
D	19.6	9.7	11.2	6.6	9.7	7.4	7.4	3.6
E	19.6	9.7	11.2	3.3	9.7	7.4	7.4	2.8

Table 2. Soil moisture tension at the 13-mm depth three times during the day.

Time	Tension, bars, at moisture levels:									
	A	B	C	D	E	A	B	C	D	E
	High temp regime					Low temp regime				
8:00 AM	0.2	0.2	0.3	0.2	0.2	0.2	0.2	0.3	0.2	0.2
1:00 PM	0.3	>15	>15	0.9	1.1	0.2	0.6	>15	0.9	1.0
4:00 PM	0.5	>15	>15	>15	>15	0.2	2.6	>15	4.8	7.5

Table 3. Soil temperature at the 13-mm depth three times during the day.

Time	Soil temp, °C, at moisture levels:									
	A	B	C	D	E	A	B	C	D	E
	High temp regime					Low temp regime				
8:00 AM	25	25	27	27	27	25	25	27	25	26
1:00 PM	53	65	67	65	64	38	42	51	43	42
4:00 PM	48	54	54	51	52	34	39	42	39	40

Table 4. Average emergence of viable seed of two species within two soil temperature regimes at five soil moisture levels.

Species	Temp	Emergence, %, at moisture levels:				
		A	B	C	D	E
Black grama	High	76.8 a; B*	0 a; A	0 a; A	63.8 b; B	23.9 b; B
	Low	84.9 a; B	77.1 b; B	3.1 a; A	90.0 b; B	83.3 b; B
Boer lovegrass	High	52.6 a; B	0 a; A	0 a; A	1.9 a; A	0 a; A
	Low	118.7 a; C	45.7 a; B	0 a; A	114.8 b; C	80.3 b; C

* Capital letters are used to compare means on the same line. Lower case letters are used for comparisons of means (1) between temperatures within species and (2) between species within temperatures. Entries having the same letters are not significantly different (0.05 level).

Table 5. Average survival of emerging seedlings on the 21st day after planting for two species within two soil temperature regimes at five soil moisture levels.

Species	Temp	Survived, %, at moisture levels:				
		A	B	C	D	E
Black grama	High	66.6 a; B	-	-	4.7 a; A	0 a; A
	Low	89.7 ab; BC	79.9 b; B	16.5;A	97.1 b; C	95.2 b; BC
Boer lovegrass	High	41.4 a; B	-	-	0 a; A	-
	Low	100.0 b; B	28.0 a; A	-	100.0 b; B	100.0 b; B

* Capital letters are used to compare means on the same line. Lower case letters are used for comparisons of means (1) between temperatures within species and (2) between species within temperatures. Entries having the same letters are not significantly different (0.05 level). A dash (-) indicates no emerging seedlings.

greater survival of black grama than of boer lovegrass under moisture level B. This was the only significant difference between species. At moisture level A survival had levelled for all entries by the close of the trial except that the survival of boer lovegrass seedlings in the high temperature regime was still decreasing. At moisture levels D and E survival of emerging black grama seedlings in the high temperature regime decreased very rapidly from the 6th to the 10th day after seeding, so that by the end of the trial there were few if any live seedlings. Survival of emerging seedlings in the low temperature regime was fairly uniform throughout the trial.

The analysis of variance for shoot heights showed a significant moisture × species × temperature interaction. In the high temperature regime within moisture level A, black grama produced significantly taller shoots than boer lovegrass (Table 6). In the low temperature regime, the shoots of black grama were significantly taller than boer lovegrass at moisture levels with surviving seedlings. At moisture level A growth of boer lovegrass in the high temperature regime was very slow, but black grama in both temperature regimes and boer lovegrass in the low temperature regime were growing rapidly at the close of the trial. At moisture level B in the low temperature regime, surviving black grama seedlings were growing rapidly but boer lovegrass seedlings had stopped growing on the 17th day after seeding. Black grama seedlings at moisture level C had ceased to grow by the close of the trial. At moisture level D boer lovegrass seedlings in the low temperature regime were growing slowly at the close of the trial but the black grama seedlings were growing rapidly. Black grama seedlings at moisture level D in the highest temperature regime ceased to grow 6 days after seeding. At moisture level E in the low temperature regime, boer lovegrass again was growing more slowly than black grama at the end of the trial.

There was a significant moisture × species × temperature interaction for the average weight per seedling. The shoots of black grama in the high temperature regime were significantly heavier in moisture level A than at any other moisture level (Table 7). In the high temperature regime, only moisture level A had surviving seedlings of boer lovegrass. In the low temperature regime, the shoot weights of black grama were reduced significantly by moisture level C. The shoot weights of boer lovegrass were significantly reduced by level B in the low temperature regime. There was no survival of boer lovegrass at level C of the low temperature regime. The shoots of black grama were significantly heavier than boer lovegrass under moisture level A within the high temperature regime. Within the low temperature regime at moisture level B, the shoots of black grama were significantly heavier than those of boer lovegrass. At moisture level A, the shoot weights of black grama were not affected significantly by the soil temperatures.

The analysis of variance for root lengths revealed a significant moisture × species × temperature interaction. The roots of black grama were significantly longer at moisture level A than at level D of the high temperature regime (Table 8). In the low temperature regime, the roots of black grama were significantly shorter at moisture level C than at all other moisture levels. The roots of boer lovegrass were significantly shorter at level B than at all other moisture levels of the low temperature regime with surviving seedlings. Black grama produced significantly longer roots than boer lovegrass at moisture level A of the high temperature regime and moisture level B of the low temperature regime. The root lengths for black grama were not affected significantly by the different soil temperatures at moisture level A.

The analysis of variance for the average root weight per seedling showed a significant moisture × temperature interaction, but no species differences. The average seedling root weight had some variation among moisture levels in the low temperature regime (Table 9). The weights were not affected significantly by the moisture levels in the high temperature regime. Seedling root weights were significantly higher in the low than high temperature regime at moisture level D.

Black grama, in the high temperature regime with continuous field capacity moisture, had a leaf temperature of 81C. In the low temperature regime, the leaf temperatures of black grama ranged from 33 to 36C,

Table 6. Average shoot height on the 21st day after planting for two species within two soil temperature regimes at five soil moisture levels.

		Shoot ht, cm, at moisture levels:				
Species	Temp	A	B	C	D	E
Black grama	High	4.1 b; B*	-	-	0.5 a; A	-
	Low	6.8 d; D	5.2 b; B	0.5; A	6.0 c; C	4.9 b; B
Boer lovegrass	High	1.2 a	-	-	-	-
	Low	5.3 c; C	0.7 a; A	-	2.8 b; B	2.8 a; B

* Capital letters are used to compare means on the same line. Lower case letters are used for comparisons of means (1) between temperatures within species and (2) between species within temperatures. Entries having the same letters are not significantly different (0.05 level). A dash (-) indicates no surviving seedlings.

Table 7. Average shoot weight per surviving seedling on the 21st day after planting for two species within two soil temperature regimes at five soil moisture levels.

		Shoot wt, mg, at moisture levels:				
Species	Temp	A	B	C	D	E
Black grama	High	1.7 b; B*	-	-	0.3 a; A	-
	Low	1.4 b; B	1.4 b; B	0.2; A	1.5 b; B	1.3 a; B
Boer lovegrass	High	0.2 a	-	-	-	-
	Low	0.8 b; B	0.2 a; A	-	0.6 b; B	0.9 a; B

* Capital letters are used to compare means on the same line. Lower case letters are used for comparisons of means (1) between temperatures within species and (2) between species within temperatures. Entries having the same letters are not significantly different (0.05 level). A dash (-) indicates no surviving seedlings.

Table 8. Average root length on the 21st day after planting for two species within two soil temperature regimes at five soil moisture levels.

		Root length, cm, at moisture levels:				
Species	Temp	A	B	C	D	E
Black grama	High	9.5 b; B*	-	-	0.3 a; A	-
	Low	9.4 b; B	8.9 b; B	1.9; A	9.3 b; B	8.3 a; B
Boer lovegrass	High	4.0 a	-	-	-	-
	Low	9.0 b; B	2.4 a; A	-	8.9 b; B	8.2 a; B

* Capital letters are used to compare means on the same line. Lower case letters are used for comparisons of means (1) between temperatures within species and (2) between species within temperatures. Entries having the same letters are not significantly different (0.05 level). A dash (-) indicates no surviving seedlings.

Table 9. Average root weight per surviving seedling on the 21st day after planting for two species within two soil temperature regimes at five soil moisture levels.

	Root wt, mg, at moisture levels				
Temperature	A	B	C	D	E
High	0.7 a; A*	-	-	0.0 a; A	-
Low	1.4 a; BC	0.7; AB	0.4; A	1.8 b; CD	2.4; D

* Capital letters are used to compare means on the same line. Lower case letters are used for comparisons of means between temperatures. Entries having the same letters are not significantly different (0.05 level). A dash (-) indicates no surviving seedlings.

and of boer lovegrass, 37 to 39C. There was some variation between species and among moisture levels in the low temperature regime, but the greatest variation occurred between temperature regimes. See Table 2 for the soil moisture at the time leaf temperatures were recorded.

DISCUSSION

The effects of five moisture levels in two temperature regimes on initial growth of black grama and boer lovegrass were studied. The percent emergence was based on the number of viable seed planted. In the high temperature regime, maintaining soil moisture at field capacity for 3 days before reducing it (moisture levels D and E) favored black grama. The high temperature regime did not reduce emergence of either species significantly within moisture levels, except for black grama at level B and boer lovegrass at levels D and E. Having moisture at field capacity for about 14 hours a day (Level C) was not sufficient for any appreciable emergence of either species irrespective of the temperature regime. Emergence of black grama was good in all moisture levels having available soil moisture at least from 5 PM (daily watering time) to 1 PM. However, emergence of boer lovegrass was reduced unless moisture was available at all times (see Tables 2 and 4). Knipe and Herbel (1960) found that black grama had over 50% germination in a 20-bar osmotic concentration and made measurable growth at 11 bars. Boer lovegrass germination was greatly reduced by the 11-bar solution and there was no measurable growth in solutions higher than seven bars. Delaying the reduction of soil moisture (levels D and E) markedly enhanced the emergence of boer lovegrass in the low temperature regime, compared to reducing soil moisture after day one. It takes boer lovegrass slightly longer to imbibe moisture and initiate germination than black grama.

Survival of emerging black grama seedlings was greatly reduced by the reduction in moisture in the high temperature regime, as at levels D and E. The higher maximum soil temperatures in those levels, when compared to A, may also be a factor (Table 3). The emergence of boer lovegrass was none or very low at any of the levels where moisture was reduced below field capacity in the high temperature regime, so that no conclusions may be made regarding survival. The reduced survival of black grama seedlings in the low temperature regime at moisture level C was definitely a result of the low moisture. In the low temperature regime survival of boer lovegrass was reduced by moisture level B. This indicates that a reduction in soil moisture a day after planting is more detrimental to survival than a later reduction, as at levels D and E. In the low temperature regime there was excellent survival of both species when the moisture level was not reduced until the 3rd day. The results of both emergence and survival of these two species at moisture level A agree very well with those found in a previous study where moisture was non-limiting (Sosebee and Herbel, 1969). Under the conditions of this trial, it took 231 mm of water (level A) during the 21-day period for any appreciable survival in the high temperature regime. In the low temperature regime it took about 70 mm. The high leaf temperature (81C) measured in black grama seedlings growing in the high temperature regime apparently did not adversely affect survival.

Black grama produced significantly taller shoots than boer lovegrass at all moisture levels except those where none survived. The height of both species was improved significantly by the low temperature regime over the high temperature regime at all levels with surviving seedlings. The shoot weight per surviving seedling of black grama was always greater than that of boer lovegrass in the same treatment, but not always at the .05 level.

The root length of black grama in the low temperature regime was adversely affected by the low moisture at level C but made good growth at the other levels. The root growth of boer lovegrass was affected adversely by moisture level B but made good growth at the other levels. There were no surviving seedlings of boer lovegrass at level C. There was no significant difference between species in root weight per surviving seedling.

The low temperature regime was more favorable for plant growth than the high temperature regime. The plants grown at moisture levels A, D, and E emerged, survived, and grew better than those grown at the other levels. Apparently, only a slight decrease in soil moisture within a day after growth initiation can be detrimental. Black grama generally outperformed boer lovegrass in the severe environmental conditions of this trial.

It is apparent that some protection must be provided to seeded species growing on an area denuded of its natural vegetation. The protection is necessary for reducing soil temperatures and evaporation losses from the soil surface.

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