Reprinted from Agronomy Journal
Vol. 61, July-August 1969, p. 621-624

Effects of High Temperatures on Emergence and Initial Growth of Range Plants[1]

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ABSTRACT

The daily soil temperatures used in this light chamber study were patterned after observations made under field conditions: 18 to 39C where the surface was sparsely shaded by brush, and 18 to 53C where the surface was left bare. The soil moisture was maintained at field capacity. Emergence of sacaton (*Sporobolus wrightii* Munro), vine mesquite (*Panicum obtusum* HBK.), bush muhly (*Muhlenbergia porteri* Scribn.), and fourwing saltbush (*Atriplex canescens* (Pursh) Nutt.) was adversely affected by the high temperature regime. Survival of all 14 accessions except rhodesgrass (*Chloris gayana* Kunth), 'Vaughn' sideoats grama (*Bouteloua curtipendula* (Michx.) Torr.), and black grama (*B. eriopoda* (Torr.) Torr.) was reduced by the high temperature regime.

At the close of the 21-day trial most species had stopped growing or were growing very slowly under the high temperature regime. The shoot weights for the plants growing in the low temperature regime averaged nearly twice as much as those growing in the high temperature regime. There was no significant difference in root weight per seedling between temperature regimes. The root lengths of black grama, 'Vaughn' sideoats grama, tobosa (*Hilaria mutica* (Buckl.) Benth.), lehmann lovegrass (*Eragrostis lehmanniana* Nees), and alkali sacaton (*Sporobolus airoides* (Torr.) Torr.) were not reduced significantly by the high temperature regime.

The high temperatures were detrimental, in one way or another, to all species even when moisture was adequate but black grama and sideoats grama performed satisfactorily.

Additional index words: **Survival, Shoot height, Shoot weight, Root length, Root weight.**

[1] Contribution from Crops Research Division, Agricultural Research Service, U. S. Department of Agriculture, and the New Mexico Agricultural Experiment Station, Las Cruces 88001. Published as Journal Series No. 307, Agricultural Experiment Station, New Mexico State University. Received Jan. 16, 1969.

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SUCCESSFUL range seeding in the Southwest is hindered by the high soil temperatures and limited moisture. The growing season is restricted by limited moisture conditions, leaving little time for the establishment of forage species. Many seeds fail to germinate, and many of the ones that germinate soon die because of inadequate moisture conditions and extremely high soil temperatures. Many seeding practices leave the surface bare and susceptible to intense solar radiation. The survival of seedlings on bare areas is greatly enhanced by shading. This study was initiated to determine the effect of two soil temperature regimes on seedling emergence and initial growth of 14 perennial warm-season range species.

Maximum soil temperatures (13-mm depth) on bare areas on the Jornada Experimental Range averaged 57C during the growing season, July to September, with 66C not uncommon. Soil protection by shrubs piled three deep, and providing sparse shade, reduced the average maximum soil temeprature approximately 21C (Herbel, 1964, unpublished report).

Laude, Shrum, and Biechler (1952) found the tolerance of perennial grass seedlings to high soil temperature decreased from germination to emergence in a temperature range from 42 to 53C. High soil temperature caused a delay as well as a reduction in seedling emergence. The growth of the surviving seedlings was impaired by preemergence heat exposures.

Laude (1957) studied the competitive ability of range grasses and weeds in relation to soil temperature. He showed that as soil temperature increased from 46 to 49C the emergence of five winter annual grasses decreased over 90%. In a comparison of a heat-tolerant perennial grass, nodding stipa (*Stipa cernua* Stebbins and Love), and a warm-season weed, rough pigweed (*Amaranthus retroflexus* L.), the pigweed was able to tolerate higher soil temperatures than the nodding stipa.

Tadmor and Hillel (1964) studied the effect of constant temperatures on germination. They found that the optimum temperature for the onset of germination was 15 to 20C for the 12 species studied. Onset of germination was not affected by alternating temperatures (Tadmor and Hillel, 1965).

MATERIALS AND METHODS

This study was conducted in a light chamber with certain conditions controlled to simulate those in the field. The masonite chamber was approximately 2.7 × 0.9 × 1.2 m. It was divided into two parts by a partition, separating the high and low soil temperature regimes. The ceiling and floor of the chamber were perforated to allow free movement of air.

Lighting and heating were supplied by an overhead bank of fluorescent lamps and three "grow lux" lamps. These lights were on from 5:30 AM until 7:00 PM. Infrared lamps were used to supplement the other lights. The high temperature regime was obtained by having four infrared bulbs on full intensity from 8:00 AM until 1:00 PM, and approximately half intensity from then until 4:00 PM. Two infrared bulbs at approximately half intensity from 8:00 AM until 4:00 PM were used for the low temperature regime. The light intensity at plant level was 6,774 lux for the low temperature regime, 8,172 for the high temperature regime low power, and 19,355 lux for the high temperature regime full power. The spectral quality was similar to sunlight, except that with the four infrared bulbs the red light was greater than sunlight and the blue and green light was lower.

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 dishes were perforated in the bottom to allow drainage of excess water and to assure proper soil aeration.

The soil moisture and temperature readings were obtained by using fiberglass units with thermistors and an ohmmeter. The units were placed at the 13-mm depth in dishes randomly located within each replication. The maximum soil temperature was 53 and 39C for the high and low temperature regimes, respectively. The minimum temperature for both regimes was 18C. Maximum temperature at the soil surface, measured with a surface thermometer, was 67 and 39C, respectively.

The seeds were planted in the morning and subjected to the heat conditions in the chamber prior to the first watering. They were watered for the first time in the evening of the 1st day and then every evening for the duration of the trial. Each dish was watered to maintain soil moisture at field capacity. Each dish in the high temperature regime received 19.6 mm water on the 1st day, 9.7 mm on the 2nd day, and 11.2 mm each day thereafter. Each dish in the low temperature regime received 9.7 mm water on the 1st day and 7.5 mm daily thereafter.

The emergence, survival, and height of the seedling were recorded daily. Upon termination of each replication, the root and top growth were separated and the average length of the roots was recorded. They were oven-dried, after each replication, for 24 hours at 93C and weighed.

An analysis of variance was used to determine significant differences, and Duncan's multiple range test (Duncan, 1957) was used to compare treatment means. The emergence data were transformed to logarithms, to improve the model and to increase the precision of the analysis. Similarly, arcsine transformations were used in the analysis of the survival data. All other analyses were on the actual data.

A randomized complete block design was used, consisting of a split plot analysis with two treatments (whole plot units), four replications, and 14 species (subplot units). The replications were with time, and they were terminated on the 21st day after planting. The 14 species, accession or variety, and original source were as follows:

Fourwing saltbush, (*Atriplex canescens* (Pursh) Nutt.), NM-155, Los Lunas, N. M.
Caucasian bluestem, (*Bothriochloa caucasica* (Trin.) C. E. Hubb.), KG-40, USSR.
Yellow bluestem (*Bothriochloa ischaemum* (L.) Keng), A-1407, USSR.
Sideoats grama (*Bouteloua curtipendula* (Michx.) Torr.), 'Vaughn,' Vaughn, N. M.
Sideoats grama (*Bouteloua curtipendula* (Michx.) Torr.), NM-28, Socorro, N. M.
Black grama (*Bouteloua eriopoda* (Torr.) Torr.), NM-44, Socorro, N. M.
Rhodesgrass (*Chloris gayana* Kunth), Lubbock Strain, Africa.
Boer lovegrass (*Eragrostis chloromelas* Steud.) A-12752, S. Africa.
Lehmann lovegrass (*Eragrostis lehmanniana* Nees), A-14328, S. Africa.
Tobosa (*Hilaria mutica* (Buckl.) Benth.), NM-327, Las Cruces, N. M.
Bush muhly (*Muhlenbergia porteri* Scribn.), A-13273, Los Lunas, N. M.
Vine mesquite (*Panicum obtusum* HBK.), A-13165, Carrizozo, N. M.
Alkali sacaton (*Sporobolus airoides* (Torr.) Torr.), NM-184, Claunch, N. M.
Sacaton (*Sporobolus wrightii* Munro), A-3659, Roswell, N. M.

RESULTS

The germination percentages (Table 1) were obtained from tests conducted on the same seed lots by the State Seed Analyst of the New Mexico State Department of Agriculture. The germinating conditions were considered to be "optimum"; petri dishes with moistened blotter paper and with alternating temperatures (20 to 35C) and alternating light and dark periods. The analysis of variance on the emergence data showed a significant species × temperature interaction. Some species, notably fourwing saltbush and rhodesgrass in the low temperature regime, had higher emergence with this treatment than in the germination tests. Emergence of lehmann lovegrass was significantly lower than any other species in the low temperature regime. The high temperature regime significantly reduced emergence of sacaton, vine mesquite, bush muhly, and fourwing saltbush. The latter three had significantly lower emergence than any other species in the high temperature regime. Emergence in the high temperature regime was 3 to 5 days later than in the low temperature regime.

The seedling survival was based upon the total number of emerging seedlings. The analysis of variance for seedling survival showed a significant species × temperature interaction. Survival of all species except rhodesgrass, Vaughn sideoats grama, and black grama was reduced significantly by the high temperature regime (Table 2). There was no significant difference in seeding survival among species within the low temperature regime. In the high temperature regime the

Table 1. Average germination and emergence of viable seed of 14 species within two soil temperature regimes.

Species	Germination, %	Emergence, %	
		High temp	Low temp
Black grama	43.5	109.8 a; A*	105.5 ab; A
Boer lovegrass	70.0	83.7 ab; A	113.6 a; A
NM-28 sideoats grama	76.5	75.9 ab; .'	75.4 abc; A
Rhodesgrass	23.0	66.4 ab; A	129.9 a; A
Alkali sacaton	62.0	54.6 abc; A	84.9 abc; A
Caucasian bluestem	34.0	45.9 abc; A	74.9 abc; A
Yellow bluestem	57.0	44.8 abc; A	106.4 ab; A
Vaughn sideoats grama	79.0	34.7 bcd; A	39.0 bc; A
Tobosa	46.0	24.0 cd; A	73.3 abc ; A
Sacaton	84.0	16.3 d; A	85.5 abc; B
Lehmann lovegrass	66.7	15.3 d; A	8.5 d; A
Vine mesquite	26.0	6.0 e; A	30.9 c; B
Bush muhly	84.0	5.9 e; A	79.5 abc; B
Fourwing saltbush	41.0	0.5 f; A	170.1 a; B

* Capital letters are used to compare means on the same line and lower case letters are used to compare means in the same column. Entries having the same letter are not significantly different (0.05 level).

Table 2. Average survival of emerging seedlings on the 21st day after planting for 14 species within two soil temperature regimes.

Species	Survived, %	
	High temp	Low temp
Rhodesgrass	90.0 a; A*	100.0 a; A
Vaughn sideoats grama	80.5 ab; A	83.7 a; A
Black grama	70.2 abc; A	82.9 a; A
NM-28 sideoats grama	60.2 bcd; A	94.1 a; B
Alkali sacaton	57.7 bcd; A	93.4 a; B
Vine mesquite	46.1 cde; A	100.0 a; B
Boer lovegrass	46.0 cde; A	93.5 a; B
Tobosa	44.5 cde; A	94.3 a; B
Lehmann lovegrass	40.6 de; A	100.0 a; B
Sacaton	39.7 de;A	94.1 a; B
Caucasian bluestem	37.5 de; A	92.1 a; B
Yellow bluestem	23.0 ef; A	90.8 a; B
Bush muhly	4.9 f; A	93.9 a; B
Fourwing saltbush	0.0 f; A	98.1 a; B

* Capital letters are used to compare means on the same line and lower case letters are used to compare means in the same column. Entries having the same letter are not significantly different (0.05 level).

Table 3. Average shoot height on the 21st day after planting for 14 species within two soil temperature regimes.

Species	Shoot height, cm	
	High temp	Low temp
Vaughn sideoats grama	8.4 a; A*	12.1 a; B
NM-28 sideoats grama	5.3 b; A	11.3 a; B
Black grama	4.5 b; A	7.0 b; B
Tobosa	3.4 b: A	11.7 a; B
Boer lovegrass	1.8 c; A	3.7 de; A
Vine mesquite	1.8 c; A	6.7 bc; B
Sacaton	1.3 c; A	4.1 de; B
Rhodesgrass	1.3 c; A	5.7 bcd; B
Alkali sacaton	1.1 c; A	4.1 de; B
Lehmann lovegrass	1.1 c; A	2.7 e; A
Caucasian bluestem	0.9 c; A	3.6 e; B
Yellow bluestem	0.9 c; A	6.5 bc; B
Bush muhly	0.9 c; A	5.4 cd; B
Fourwing saltbush	0.0 c; A	4.9 d; B

* Capital letters are used to compare means on the same line and lower case letters are used to compare means in the same column. Entries having the same letter are not significantly different (0.05 level).

survival of all species, except vine mesquite and rhodesgrass, was declining at the close of the trial.

At the close of the trial, the high temperature regime had significantly reduced the average shoot height of all species except lehmann and boer lovegrass (Table 3). In the high temperature regime, the shoots of Vaughn sideoats grama were significantly taller than those of any other species. The shoots of NM-28 sideoats grama, black grama, and tobosa did not differ significantly from each other, but they differed significantly from all other species. Within the low temperature regime the shoots of tobosa and both varieties of sideoats grama were significantly taller than all other species. In the low temperature regime virtually all species were growing rapidly. However, in the high temperature regime all species (except tobosa, lehmann lovegrass, Vaughn sideoats grama, black grama, and NM-28 sideoats grama) had stopped growing or were growing very slowly.

Analysis of variance for shoot weight per surviving seedling indicated that the species × temperature interaction was not significant. However, there was a significant difference among species and between temperature treatments. The plants growing in the low temperature regime had significantly higher shoot weights than those in the high temperature regime, 2.86 to 1.51 mg, respectively. Vaughn and NM-28 sideoats grama had significantly higher shoot weights than all other species except tobosa and vine mesquite (Table 4).

Analysis of root weight per surviving seedling showed that the species × temperature interaction was not significant. The difference between temperatures was not significant but the difference among species was

Table 4. Average root and shoot weight per surviving seedling on the 21st day after planting for 14 species within two soil temperature regimes.

Species	Root wt, mg	Shoot wt, mg
Vaughn sideoats grama	8.5 a*	4.1 a
Vine mesquite	8.2 ab	3.5 abc
NM-28 sideoats grama	7.4 ab	5.0 a
Tobosa	6.6 ab	3.9 ab
Rhodesgrass	5.7 abc	2.3 bcd
Yellow bluestem	3.5 bcd	2.0 cd
Fourwing saltbush	2.3 cd	1.6 d
Black grama	2.2 cd	1.9 cd
Bush muhly	2.0 cd	0.9 d
Boer lovegrass	1.5 d	1.1 d
Sacaton	1.2 d	1.0 d
Caucasian bluestem	1.2 d	1.0 d
Alkali sacaton	1.2 d	0.7 d
Lehmann lovegrass	1.1 d	1.5 d

* Lower case letters are used to compare means in the same column. Entries having the same letter are not significantly different (0.05 level).

Table 5. Average root length on the 21st day after planting for 14 species within two soil temperature regimes.

Species	Root length, cm	
	High temp	Low temp
Black grama	9.7 a; A*	6.0 c; A
Vaughn sideoats grama	9.6 a; A	12.1 a; A
NM-28 sideoats grama	8.6 ab; A	13.2 a; B
Tobosa	6.3 abc; A	9.9 abc; A
Lehmann lovegrass	5.6 abc; A	6.9 bc; A
Boer lovegrass	4.6 bcd; A	9.5 abc; B
Rhodesgrass	4.6 bcd; A	9.7 abc; B
Caucasian bluestem	4.2 cde; A	8.5 abc; B
Alkali sacaton	3.8 cde; A	5.7 c; A
Sacaton	3.6 cde; A	8.7 abc; B
Vine mesquite	2.9 cde; A	10.4 abc; B
Yellow bluestem	1.5 de; A	11.6 ab; B
Bush muhly	0.7 de; A	8.8 abc; B
Fourwing saltbush	0.0 e; A	10.8 ab; B

* Capital letters are used to compare means on the same line and lower case letters are used to compare means in the same column. Entries having the same letter are not significantly different (0.05 level).

significant (Table 4). Vaughn sideoats grama had the highest root weight per seedling but was not significantly different from vine mesquite, NM-28 sideoats grama, tobosa, or rhodesgrass.

The species × temperature interaction for average root lengths was significant. The root lengths of black grama, Vaughn sideoats grama, tobosa, lehmann lovegrass, and alkali sacaton were not reduced significantly by the high temperature regime. There was greater variation among species in the high temperature regime than in the low temperature regime (Table 5).

Analysis for shoot:root ratios (by weight) showed a nonsignificant species × temperature interaction and no significant difference among species or between temperatures. The average ratios for the high and low temperature regimes were 1:1.2 and 1:1.7, respectively.

DISCUSSION

We studied the effects of two soil temperature regimes on 14 accessions. The high temperature regime did not reduce significantly the emergence of most. However, the 3- to 5-day delay in emergence could be fatal under field conditions if soil moisture were not available for continuous growth. The low temperature regime was more favorable for germination of some species (notably fourwing saltbush, rhodesgrass, and boer lovegrass) than the conditions considered "optimum," even though both tests were with the same seed lot. The "optimum" conditions were those common for laboratory germination: petri dishes with permanent moisture, and alternating temperatures as well as light and dark periods. In this study, fourwing saltbush had 170.1% emergence under alternating temperatures of 22 to 39C, with alternating light and dark periods. Gerard[3] found that maximum germination of fourwing saltbush occurred with alternating light and dark periods with alternating temperatures of 16 to 24C. The emergence of black grama exceeded 100% in the high and low temperature regimes, but emergence of this species was not as high as with fourwing saltbush, rhodesgrass, or boer lovegrass in the low temperature regime (although differences among these species were not significant). Some variation could perhaps be due to the cyclic nature of dormancy that apparently alters the germination of lehmann lovegrass, and other species, with time. Because the replications were with time, we do not believe that this accounted for much variation. The real difference might be attributed to the soil medium. The germination test conducted by the State Seed Analyst, with use of petri dishes at temperatures of 20 to 35C, resulted in lower percentages than those obtained by using a soil medium with temperatures of 22 to 39C. The percentages for germination of fourwing saltbush in petri dishes at temperatures of 16 to 24C were lower than those obtained with a soil medium.[3]

Emergence is an uncertainty on seeded arid ranges; but even with good emergence, survival may be poor. Because of seasonal moisture, seeding must be done in the summer, which leaves limited time for establishment of seedlings before frost. Some seedlings died shortly after emergence and others emerged late; therefore, we did not report the survival as 100% in most cases. The low temperature regime was most favorable for survival of all species except black grama, Vaughn sideoats grama, and rhodesgrass. These three species had relatively high survival 21 days after planting in the high temperature regime. However, it seems likely that survival of most species in the high temperature regime would have been even lower if the trial had been prolonged. Survival of seedlings in the low temperature regime did not differ significantly among species, and it was static at the close of the trial.

The low temperature regime was more favorable for shoot growth in all species except lehmann and boer lovegrass. In the low temperature regime, tobosa and both varieties of sideoats grama were significantly taller than all other species. Vaughn sideoats grama produced a significantly greater height in the high temperature regime than all other species. This indicates that surviving seedlings of Vaughn sideoats grama are able to tolerate high soil temperatures. An examination of records of daily shoot growth in the high temperature regime indicated that many species were growing poorly or not at all by the close of the trial. However, as long as they could survive they could grow when temperatures were moderate (e.g., near the end of summer). Also, the taller ones had made enough growth to overwinter even if they made no further growth.

Both varieties of sideoats grama had the highest shoot weight per seedling but they were not significantly different from tobosa or vine mesquite. The individual leaves of vine mesquite were larger than the other seedlings, but leaves were fewer for each seedling. The weight and height of the shoots indicate the amount of leaf surface area of the seedlings. The greater the leaf surface area, the more photosynthesizing tissue there is for the manufacture of carbohydrates. This is essential for the growth of the seedling and for production of reserves for storage. However, transpiration may also be greater in plants with larger leaves. Therefore, large leaves could be a poor adaptive feature of arid zone plants.

Although black grama did not produce an outstanding shoot height or weight in the high temperature regime, it produced the longest roots—even though it did not differ significantly from either variety of sideoats grama, tobosa, or lehmann lovegrass. Vaughn sideoats grama had the highest root weight but was not significantly different from vine mesquite, NM-28 sideoats grama, tobosa, and rhodesgrass. NM-28 sideoats grama had only one surviving seedling; therefore its weight was not representative. Sixteen seedlings emerged, within the high temperature regime, and produced a measurable root growth, even though all but one died.

The shoot:root ratios were not significantly different, a factor indicating that those plants producing little shoot growth also produced little root growth, and vice versa.

The high temperatures observed under range conditions are detrimental, in one way or another, to all species even when moisture is adequate. Few seedlings are likely to survive unless they are artificially protected from solar radiation, or unless the summer temperatures moderate after the seedlings have begun to grow.

[3] Gerard, J. B. 1965. Factors and treatments affecting fruit fill, seed germination, seedling emergence of fourwing saltbush (*Atriplex canescens* (Pursh.) Nutt.). M.S. Thesis. New Mexico State University.

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