Effect of Stage of Seedling Development upon Heat Tolerance in Bromegrasses[1]

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VEGETATION on the range characteristically encounters intervals of hot weather. The high temperatures which prevail at such times may be decidedly injurious to plants. Especially is this so when the heat occurs at a critical stage in the development of the plant. The early stages of seedling growth warrant particular study as they constitute one of these critical periods and are of the utmost importance in stand establishment.

High temperatures affect a planting from the time the seed is placed in the ground. It has been demonstrated that hot weather and the resulting high soil temperatures of the seedbed during the pre-emergence period may seriously impair the emergence of grasses (Laude, Shrum and Biehler, 1952). The response of the perennial grass seedling to heat immediately after emergence, however, has received little attention, as most available studies deal with plants of greater age.

Schultz and Hayes (1938) subjected grasses 30 or 60 days of age to heat and dryness and concluded that the older seedlings had the greater resistance. McAlister (1944) noted the importance of seedling age in drought testing. He was unable to separate strains of slender wheatgrass and of smooth brome by use of a drought chamber when the seedlings were 1 month old, but could do so when the plants were 6 to 8 weeks old. Based on a study of the behavior of 14 species of prairie grasses subjected to artificially produced hot wind when 3 to 6 weeks of age, Mueller and Weaver (1942) reported that age of the seedling had but little influence on the response.

The heat tolerance of corn has been studied in the earlier stages of development. Young seedlings 10 to 12 days after planting were found to possess considerably more resistance to a given heat stress than were those 16 to 20 days old (Heyne and Laude, 1940). Sweet corn strains 15 days of age were reported to be more heat tolerant than those 29 days of age (Haber, 1938).

The experiments reported in this investigation were designed to supply information concerning the heat tolerance of bromegrass seedlings during the early stages of development following emergence.

Materials and Procedure

The three bromegrasses employed in these tests are extensively used in range seedings in California. They are mountain brome (*Bromus marginatus*), prairie brome (*Bromus catharticus*), and Harlan brome (*Bromus stamineus*). Love, Sumner, and Osterli (1952) discuss the origin and growth habit of these species.

Plants were grown in the greenhouse

[1] A portion of the data was included in a thesis submitted by the junior author at the University of California in partial fulfillment of the requirements for the degree of Doctor of Philosophy.

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and compared as to heat tolerance by exposure to high temperature in a controlled environment chamber. Unless otherwise noted, the procedure was as follows. Seed was planted in 6-inch clay pots at ½-inch depth in a mixture of ⅔ loam soil and ⅓ sand. Thinning after emergence reduced the number of seedlings for testing to 6 per pot for the younger ages and 3 for the older. All pots were watered sufficiently to maintain soil moisture well above the permanent wilting percentage throughout growth. The plants remained on greenhouse benches except when in the testing chamber. Prevailing greenhouse temperatures were approximately 60°F. at night and 75° to 80°F. during the day, with occasional daily maxima of 90°F. being obtained in the warmest weather.

Ages of the plants are stated in days after seeding. Plantings made at scheduled intervals supplied the material of different ages on the same day. This reduced the variation in growing conditions prior to the test and permitted the testing together of a series of ages in the same high temperature exposure thus insuring that all received the identical heat stress. The testing chamber accommodated approximately 40 pots at a time. Sufficient numbers of plants to evaluate each condition were obtained through repeated tests, usually conducted on successive days.

The controlled environment unit consisted of an insulated chamber, 160 cubic feet in size, through which air of precisely regulated temperature and humidity was passed. Light of approximately 600 foot candle intensity was supplied by a panel of fluorescent tubes. Positional effects within the unit were eliminated by placing the pots on a slowly revolving turntable.

Test conditions were employed which would yield differential injury among the ages and species. It was found that such resulted when material was subjected to air at 130°F. and 30 to 35 percent relative humidity for 4¾ hours. Under these conditions the dryness of the air (saturation deficit) was somewhat greater than that generally encountered in the field when plants are under stress at considerably lower temperatures and relative humidities. In operation the unit was heated to 130°F., then opened for introduction of the plants. The duration of exposure was timed from the moment the unit regained a temperature of 130°F. All heat exposures were commenced between 9 and 10 a.m. on the test day.

Injury was determined by measurement 7 days after a test. The total length of leaf per plant was obtained by summing individual leaf lengths measured along the mid-rib. A percent injury was computed by expressing the length of dead leaf tissue as a percentage of the total leaf length. With older seedlings having more than three leaves, the measurements were confined to the three youngest leaves exposed on the day of the test.

Results and Discussion

Plant Age and Heat Tolerance

The earliest stage at which it was feasible to study the emerged seedling in these species was the seventh day after planting. Under greenhouse conditions the first seedlings appeared above ground on the fifth day and emergence was essentially complete by the eighth day. For example, of the total emergence of prairie brome in one trial, 11 percent occurred on the fifth, 64 percent on the sixth, 19 percent on the seventh, and 6 percent on the eighth day after planting. Mountain brome followed essentially this pattern while Harlan brome emerged somewhat earlier, having a greater percentage up on the fifth day.

The three bromes were subjected to the uniform heat test at ages of 7 to 70 days. The highest level of heat tolerance was obtained in seedlings of these species when 7 or 8 days of age, namely, just after emergence. At this stage there was no visible injury produced. However, older material was decidedly injured as shown in Table 1. The most striking change in heat tolerance is the rapid loss noted between the period shortly after emergence and approximately 14 days. Relatively low tolerance then persists through the age of 28 days, after which an increase in heat tolerance with age is evidenced. The reduced rate of gain in tolerance between 56 and 70 days and the apparent loss shown in prairie brome at this period, are likely due to the relatively large plant size in relation to pot size and the development of a somewhat root-bound condition.

TABLE 1

Percent injury in three species of bromegrass subjected to a uniform high temperature test at several ages

AGE IN DAYS AFTER PLANTING	MEAN PERCENT INJURY*		
	Mountain brome	Prairie brome	Harlan brome
14	100.0	38.2	100.0
18	—	66.0†	—
28	100.0	64.2	96.0
42	76.0	49.0	66.2
56	50.5	31.8	46.2
70	42.0	38.2	45.5

* Least significant difference at 5% level = 6.2%.

† This figure, obtained from other tests, was not included in the analysis of variance.

These results suggest that high temperature in itself is not likely to injure the grass seedling during the first 3 or 4 days following emergence. Conditions which often accompany high temperatures in the field, such as dry surface soil, would appear likely to be more damaging to a stand at this time. The two-week period commencing some 5 or 6 days after emergence, however, is one of low heat tolerance in the plants tested, and is a period during which high temperatures alone appear capable of inflicting extensive damage to a stand.

In this study comparison of a series of similar ages by controlled environment testing, permitted the separation of the species as to heat tolerance. Prairie brome evidenced superior heat tolerance except for the period immediately after emergence when the three species responded alike to the conditions employed. It has not yet been determined whether a more severe heat stress would separate these species at this stage.

It is evident that caution is required in stating relationships between temperature tolerance and age of plant. In this study the tolerance of a species could be correctly stated to increase or to decrease with age depending upon the stages of development compared.

Development of Heat Hardiness

The plants previously discussed were not hardened prior to testing. Experiments were conducted to determine the degree of hardiness that could be attained by conditioning the plants to high temperatures prior to the heat test. Three hardening treatments were used according to a schedule which prepared all plants for testing together on the thirty-first day after planting. This placed the heat hardening treatments in a period when heat tolerance of the unhardened plant was relatively low.

Treatment A subjected the plants to a 30-minute exposure to 130°F. every third day commencing with the eleventh day after planting. Seven such exposures were given this group before the final heat test.

Treatment B subjected the plants to 1 hour at 110°F. on the 25th day, 2 hours at 120°F. on the 27th day, and 3 hours at 130°F. on the 29th day after planting.

Treatment C followed the same age and duration of exposure schedule as B, but all exposures were to 130°F. The final test on the 31st day was 4¾ hours at 130°F.

Results are presented in Table 2. No significant difference existed among the three hardening procedures for any one species. However, each of the three bromegrasses attained an unquestionably significant degree of hardiness compared to its control. In agreement with such behavior is the observation that high temperature injury in the field may be less severe if gradually rising temperature, rather than an abrupt change, prevails in advance of the hot period.

TABLE 2

Percent injury after heat hardening in bromegrasses tested when 31 days of age

HEAT HARDENING TREATMENT	MEAN PERCENT INJURY*		
	Mountain brome	Prairie brome	Harlan brome
A	29.5	7.8	33.2
B	20.3	9.5	25.1
C	30.2	14.5	27.3
None	89.8	75.5	85.8

* Least significant difference at 5% level = 15.2%.

The Nature of Early Tolerance

It was noted that cloudiness preceding a heat test, in comparison with bright clear weather, was reflected in a lower level of heat tolerance in bromegrasses at least two weeks of age. The reduced light intensity, however, appeared to have no effect on the response of the seedlings which had just broken the soil surface.

Experiments were designed in which prairie bromegrass was compared for heat tolerance at ages of 8, 14, and 21 days when the seedlings either had received approximately 4 hours of morning daylight before the test or had been kept in darkness since the previous evening. After this latter group was placed in the dark, all light was excluded from them except that received during the three-minute interval in which the plants receiving morning light were introduced into the test chamber. The test chamber remained dark during the heat exposure. Differential injury was obtained with this material by heating the chamber from room temperature to a maximum of 130°F., this temperature being maintained during the last 90 minutes of a 3½ hour heat stress.

Percent injury measured seven days after this high temperature treatment was 0.0, 31.8, and 45.0 percent respectively for those seedlings 8, 14, and 21 days of age which received morning light. Injury in plants of the dark treatment was 0.0, 86.2, and 97.9 percent respectively at the ages of 8, 14, and 21 days. The absence of light preceding the heat exposure was reflected in a distinct reduction in heat tolerance for the two older groups of seedlings.

In other tests the same heat stress was used on seedlings 7 days old. Plants for the dark treatment emerged in darkness and were kept in the dark until after the test, while seedlings for comparison emerged in the greenhouse. In contrast with the response of older seedlings, no visible injury was obtained on either the seedlings emerging in the dark or those emerging in the light. It is suggested, therefore, that the high level of heat tolerance in bromegrass seedlings which have just broken the soil surface is not contingent upon the daylight received upon emergence. Rather it appears to be related to the presence of unused food reserves stored in the endosperm of the seed and still available to the seedling at this early stage of growth. Additional study will be required to clarify further the nature of the high heat tolerance noted in the newly emerged grass seedling.

The greater injury obtained with seedlings of the dark treatment at ages of 14 and 21 days agrees with the findings of H. H. Laude (1939) who worked with species of several field crops. He noted that those plants deprived of morning light during the forenoon of the day of test exhibited greatly reduced heat resistance.

Summary

The heat tolerance of seedlings of mountain, prairie, and Harlan bromegrass was studied during early stages of post-emergence development. Behavior at these stages is particularly important in stand establishment. The desired test conditions were obtained in a precisely controlled environment chamber. This permitted the separation of the temperature responses from those of other factors often associated with warm weather in the field.

The following results were obtained:

1. Significant differences in heat tolerance were obtained among the three species. Prairie bromegrass exhibited the highest level of heat tolerance in these tests.

2. A trend of heat tolerance related to the age of the plant was found in these bromegrasses. When unhardened plants were subjected to a uniform heat stress at ages from emergence to 70 days after planting greatest heat tolerance prevailed at 7 and 8 days (immediately after emergence). Rapid loss occurred near 14 days of age. The resulting period of low tolerance persisted until approximately 28 days, after which heat tolerance gradually increased with age.

3. This trend in heat tolerance with age suggests that damage to a new stand directly attributable to high temperature would be most severe during a two-week period commencing some 5 or 6 days after emergence.

4. Distinct hardiness to heat was attained by the bromegrasses when subjected before testing to brief periodic high temperature exposures totaling 6 hours or less.

5. The heat tolerance of newly emerged seedlings compared to older seedlings differs in respect to the effect of light. In these tests absence of light before a heat stress reduced the tolerance of the older seedling but did not visibly alter the high heat tolerance of the seedling just emerged. This behavior is likely related to the presence of unused food reserves in the seed which are still available to the very young seedling.

LITERATURE CITED

Haber, E. S. 1938. A study of drought resistance in inbred strains of sweet corn, *Zea mays* var. *rugosa*. Iowa Agr. Expt. Sta. Res. Bul. 243. 18 pp.

Heyne, E. G. and H. H. Laude. 1940. Resistance of corn seedlings to high temperatures in laboratory tests. Jour. Amer. Soc. Agron. 32: 116–126.

Laude, H. H. 1939. Diurnal cycle of heat resistance in plants. Science 89: 556–557.

Laude, Horton M., Jeffrey E. Shrum, Jr., and Wayne E. Biehler. 1952. The effect of high soil temperatures on the seedling emergence of perennial grasses. Agron. Jour. 44: 110–112.

Love, R. M., D. C. Sumner, and V. P. Osterli. 1952. Improving California brush ranges. Calif. Agr. Expt. Sta. Cir. 371. 38 pp.

McAlister, Dean F. 1944. Determination of soil drought resistance in grass seedlings. Jour. Amer. Soc. Agron. 36: 324–336.

Mueller, Irene M., and J. E. Weaver. 1942. Relative drought resistance of seedlings of dominant prairie grasses. Ecology 23: 387–398.

Schultz, H. K., and H. K. Hayes. 1938. Artificial drought tests of some hay and pasture grasses and legumes in sod and seedling stages of growth. Jour. Amer. Soc. Agron. 30: 676–682.