THE RESISTANCE OF STRAINS OF BROME GRASS TO HIGH TEMPERATURES

by

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INTRODUCTION

The severe drought years of the past decade have forcibly impressed upon the minds of farmers, agrostologists, and other research workers the importance of drought resistance in pasture grasses. Weaver and Albertson (1936) following the severe drought years of 1933 and 1934 made the following observations:

> Ungrazed prairies of south central Kansas lost sixty percent of the basal cover, various types moderately grazed thirty-six percent and others heavily grazed seventy-four percent. Losses in the same sequence in north central Kansas were fifty, fifty-four, and ninety-one percent respectively. Conditions were most severe in the west central part where ungrazed prairies lost eighty-five percent, moderately grazed areas seventy-two percent and heavily grazed ones ninety-one percent.

They concluded that the destruction was caused chiefly by deficient soil moisture, extremely high temperatures, low humidity, high wind movement, and burial by dust. Savage (1937) stated in regard to the large percentage of native grasses in the central and southern Great Plains that were killed in the severe drought years of 1933 and 1934 that soil blowing, overgrazing, and climatic extremes were the principal causes of destruction with the factor of climatic extremes being far the most important.

The ability of a grass plant to withstand drought is equally important in all stages of its growth. Resistance to drought in the seedling stage may mean the difference between a full and partial stand or no stand at all. Spring seedings of grasses often have failed because of early season droughts. In some cases fall seedings of grasses have been injured because of fall droughts. Drought resistance in the mature plants is also important in maintaining established stands. This fact is demonstrated by the foregoing statements of Weaver and Albertson.

It is generally agreed that grass forms an important part of a well balanced system of agriculture. Several factors have combined during the past few years to emphasize this importance. These factors include droughts, dust storms, overgrazing, and high temperatures.

Many thousands of acres of grassland that should never have been disturbed in low rainfall areas have been plowed up and put under cultivation for the purpose of growing cash crops. During the drought years of the 1930's the land continued to be tilled, and because of the drought there was very little growth made by crops that were seeded. Consequently there was only a small amount of crop residues to hold the soil in place. The result was that the soil was left exposed to high winds which gave rise to the dreaded dust storms that prevailed during the drought years. These storms did untold damage to growing crops and pasture lands in addition to causing much human suffering and hardship. Pastures had long been overgrazed, but were even more heavily taxed to overcome the effects of the drought and dust storms. As a result of the combined effects of the drought, dust storms, overgrazing, high temperatures, and poor management practices, native pastures were soon in a very depleted condition as evidenced by the findings of Weaver and Albertson (1936).

Many pastures have made a remarkable recovery within the past three years but there still remain a large number of pastures that would be greatly benefited by the use of improved grazing practices. There also exist large areas of both fertile and marginal land which are now being tilled but which should be returned to grass. However, because of several factors such as seed bed preparation, moisture conditions, etc., it will be a much more difficult task to return the areas to grass than it was to break them up. Therefore any research which may be developed to facilitate the reseeding of cultivated fields to grass and the improvement of old pastures will serve a very definite purpose in our agricultural program as it exists today.

During recent years brome grass (Bromus inermis Leyss.) has attracted increasing attention because of its extreme winter-hardiness, its drought resistance, and its high yield of palatable forage. It is also a desirable forage grass because of the relative ease with which the seed may be harvested and with which new stands may be established.

Brome grass was introduced into the United States from northwestern Europe in the region of Norway, Sweden, Denmark, Germany, France, and the low countries Holland and Belgium. In the United States it has proved most valuable in the northern Great Plains, the Intermountain Region, and in the north central states in pastures and meadows (Fig. 1). Its region of adaptability appears to be gradually extending southward.

In view of the increasing importance of brome grass it was thought desirable to ascertain whether physiological differences

Fig. 1. Map of the United States showing the region where *Bromus inermis* is well adapted and of primary value. Copied from U. S. Dept. of Agric. Yearbook. 1937.

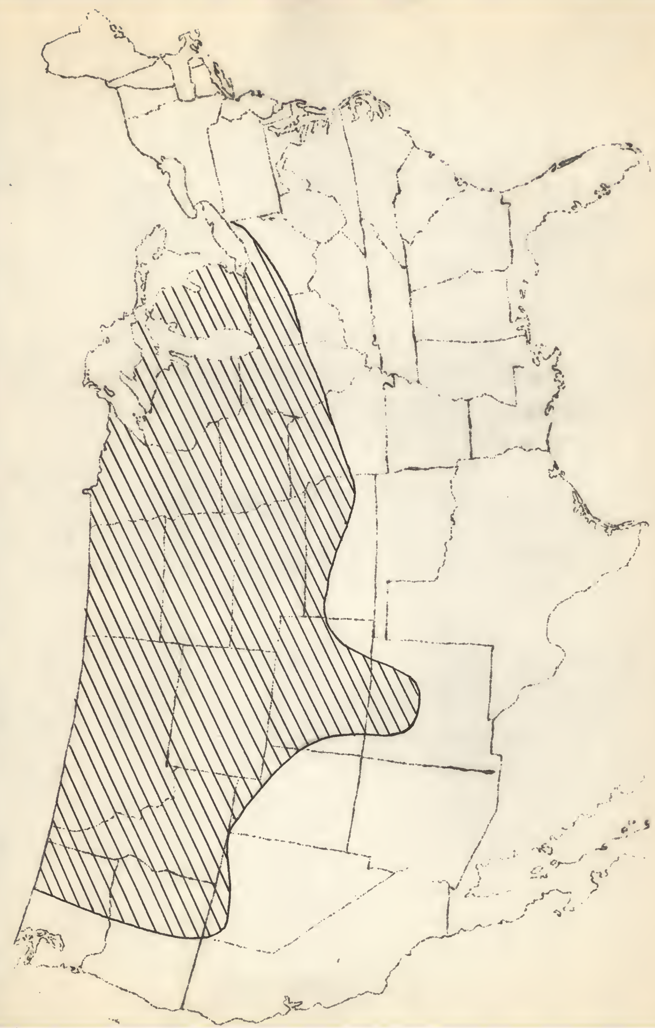


Figure 1.

in resistance to high temperatures exist between strains of brome grass collected from several different sources.

LITERATURE REVIEW

A considerable amount of research work has been conducted in regard to the drought resistance of various crop plants such as corn, wheat, and sorghum, but comparatively little such work has been done with respect to the forage grasses.

The term drought in local usage, according to Ellis, Schafer, and Caldwell (1936) "indicates a condition under which the regional vegetation and crops are not able to obtain sufficient moisture for normal growth in that region." They also stated that drought is not a simple phenomenon for it involves atmospheric drought, which is general in its scope; soil drought, which may be either local or general; and physiological drought which is extremely localized because of salt concentrations in the soil.

Factors influencing drought resistance include those concerned in absorption, transpiration, and wilt endurance. Newton and Martin (1930), working with various crop plants concluded that the colloidal properties of leaf tissue fluids are important in water retention under droughty conditions. They determined these and other physicochemical properties in a number of cereals, grasses, and other plants in relation to known drought adaptations and found that bound water content was the most dependable of the properties studied in determining the relative drought resistance of plants. The cultivated wheats and several grasses were satisfactorily arranged in the order of their drought resistance on this basis.

Dillman (1931) found that small but significant differences existed in water requirements of different varieties of the same crop. He concluded, however, that this is probably not a dependable measure of the drought resistance of a crop variety. It was his opinion that a low water requirement suggested adaptation to drought, but that the final measure of the value of a variety must be the actual yield as determined by plot tests.

Timofeeva (1933) stated that when germinating seed was subjected to a water deficiency in sugar solutions a greater percent of drought resistant plants survived as compared with those which were nonresistant. It was his opinion that drought resistance must be studied as a whole, as a single process conditioned not only by the physico-chemical properties of the protoplasm, but also by other physiological and anatomical characters such as the structure and size of the root system, pubescence of the leaves and stems, etc., also that the investigations of many fields should be correlated.

That cold resistance and drought resistance in plants are correlated was shown by Novikov (1934). In the case of cold resistance the cell loses its water by the intercellular formation of ice crystals and in the case of drought by transpiration. He found that cold and drought resistant plants had more bound water and that non-drought resistant plants lost bound water more quickly than drought resistant plants. He also found that light rainfall causes bound water to decrease rapidly, which may explain the harmful effect of insignificant rainfalls during a drought.

Aamodt and Johnston (1936) found that hardening of wheat plants by soil drought or by limited exposure to atmospheric drought increased their resistance to exposures of severe atmospheric drought.

Hunter, Laude, and Brunson (1936) were able to distinguish among strains of fourteen day old corn plants with respect to resistance to artificial drought. They obtained an almost perfect correlation between survival values of seedlings after treatment and field behavior of the inbred strains tested.

Bayles, Taylor, and Bartel (1937) were able to demonstrate clearly, differences between certain varieties of spring wheats in their resistance to artificial drought, but smaller differences were not so clearly defined. The evaluations thus obtained were consistent with the field performance of the same varieties under drought conditions.

Schultz and Hayes (1938) subjected thirty and sixty day old seedlings and sod material of a number of forage grasses and legumes to artificial drought conditions and obtained results that were in good agreement with those obtained from field trials. Crested wheatgrass and brome grass were consistently the most drought resistant of the grasses and alfalfa the most resistant of the legumes. They concluded that artificial drought resistance tests could be used to indicate those species or varieties of plants which could be expected to be the most drought resistant in the field.

Laude (1939) after working with young plants of several species of crop plants reported that a daily cycle of resistance to heat existed in these crops. He showed that "the daily maximum resistance to heat by plants was attained at about mid-day and continued during the afternoon. The minimum resistance prevailed early in the morning. Resistance to heat increased in plants when they were exposed to light and decreased when in the absence of light. One hour of light following normal darkness of night was long enough for plants to acquire a measurable, and in some cases a marked amount of resistance to heat. Ordinarily, plants reached their daily maximum heat resistance within four hours after exposure to daylight following normal night. Plants exposed to electric light during the night were more resistant to heat in early morning than those that had been in the dark during the night. The loss of heat resistance was slower than the gain of resistance in the presence of light."

Heyne and Brunson (1940), as a result of tests conducted by them concluded that heat tolerance in maize was definitely inherited and in most of the cases studied was intermediate to dominant. They also concluded that hybrid vigor in itself, apparently does not make a cross resistant to heat, at least not in the seedling stage.

The resistance of corn seedlings to artificial drought conditions was studied by Heyne and Laude (1940) who found a high correlation with the behavior of the same strains under field conditions. From their results they concluded that the testing of seedlings for heat resistance could be relied upon with considerable assurance for distinguishing differences in drought tolerance of larger plants of different strains of maize, and that a high temperature test is a valuable supplement to field studies of drought resistance.

METHODS AND MATERIALS

It is an accepted fact that different strains of the same species of plants may often respond differently when grown under the same or different conditions. This problem was designed to determine as nearly as possible whether or not differences in resistance to high temperatures exist between strains of *Bromus inermis* collected from various sources.

Seed was obtained from several different sources including Canada, Illinois, Wisconsin, Missouri, and Kansas. The Canada seed was from plants grown at Saskatchewan and the Wisconsin seed was from plants grown at Madison, but the strain originally came from Canada (Parkland Selection). Two Illinois strains were used, one of which came originally from Canada and the other from Kansas. The two Missouri strains were developed by the Missouri Agricultural College. Of the Kansas strains, two, H-14 and SB-1, were from the Kansas Agricultural Experiment Station grass Nursery at Manhattan. The strain "Local" was from brome grass growing along the roadside near Manhattan, while the three remaining strains, Chas. Sweet, Crotty, and Jeanerett, are strains being grown by farmers in Kansas, with the same respective names. The Chas. Sweet strain came from a field of brome grass in Jewell County Kansas. This grass has been growing for at least fifteen years under rather adverse conditions. The Crotty strain came from Coffey County. It was first seeded in 1900 but was plowed up, except for a small corner, because of failure to secure a stand. The seed for this study came from the grass in that small corner which has grown there since it was first seeded in 1900. In 1896 Mr. Jeanerett seeded some brome grass in southern Lyons County. This strain, called Jeanerett, is still being grown on the Jeanerett and neighboring farms.

Seed of each of these strains was planted in 6-inch clay pots and the seedlings were later transplanted into 4-inch pots, three plants per pot. Thirty-nine pots of each strain were kept in the greenhouse under uniform conditions and subjected to the high temperature treatment at the age of 65 to 75 days.

The heat treatment consisted of placing three pots of each strain within a chamber in which the temperature could be controlled. The time of the treatment varied from seven hours to nine and one-half hours and the temperature from an average of 123° F. to 136° F. No definite temperature or period of time was demed necessary because physiological differences in the reaction of the various strains to high temperatures was the thing being studied. While the plants were in the heat chamber they were observed at frequent intervals and when wilting had occurred they were removed to the greenhouse where they were watered and those which had not been destroyed by heat were allowed to continue growth. Several days after removal of the pots from the heat chamber estimates were made of the percent of top growth tissue killed or injured, and the percent of plants killed by the treatment was determined still later. The differences between injured and non-injured tissue were clearly defined three or four days after treatment when the injured tissue had dried and become brown whereas immediately following the treatment all tissue appeared similar. The determination of the percent of plants killed was made at a later date than the estimate of tissue damaged because many plants which at first appeared to have been killed would send up shoots from their roots a few days after the treatment and continue their growth.

After this test was completed, seed of what appeared to be the best six strains as a result of the first trial was planted in 4-inch pots and the plants later thinned to five per pot. There were fifty pots of each strain in this group. This test was similar to the first except that five pots of each strain were subjected to the treatment at one time. The Jeanerett strain was not included in this series of tests because seed was not available.

Determinations of the average number of culms per plant, average width of leaf, and average height of plant for each strain were made on the first group.

EXPERIMENTAL RESULTS

The most desirable strain of brome grass would be one which possessed a combination of all the more desirable morphological characteristics, desirable growth habit and form, and high resistance to injury by high and low temperatures and by drought. Although it is almost impossible to obtain such a combination of characters in any one strain it at least affords a desirable goal.

By observing the data in Table 1 it can readily be seen that considerable variation exists between strains for the characters studied. For instance, the Jeanerett and Crotty strains, with a high value for plant height, number of culms per plant, and width of leaf, would appear to be highly desirable types, while such strains as Saskatchewan, with low plant height, low number of culms per plant, and narrow leaves, would not be as desirable from the standpoint of yield. The SB-1 strain with an average plant height of 10.86 inches and leaf width of 6.17 mm. might appear to be a rather desirable type, but the fact that it has a small number of culms per plant tends to make it a rather stemmy type of plant. On the other hand, an intermediate type of plant such as the Chas. Sweet strain, with a shorter plant, narrow leaves and a large number of culms per plant is a highly desirable type because of its leafiness and lack of steminess. In general, those plants with the greater number of culms are more leafy. The Madison, Wisconsin, strain displayed a rather short, erect growth but was rather leafy. This strain has a

Table 1. Average plant height, number of culms, and width of leaf of the strains studied.

Strain	Av. height in inches	Av. no. of culms per plant	Av. width of leaf in mm.
Jeanerett	10.31	2.15	5.65
Chas. Sweet	8.71	2.10	4.85
H-14	8.88	1.57	5.15
Crotty	11.36	2.25	5.40
Madison, Wisconsin	7.79	2.15	4.22
Ill. Orig. Kansas	8.65	1.69	4.65
SB-1	10.86	1.56	6.17
Mo. Pg. 207	8.68	1.43	4.60
Saskatchewan, Canada	7.39	1.76	3.79
Ill. Orig. Canada	9.78	1.83	5.13
Local	9.61	1.41	4.89
Mo. Pg. 200	9.94	1.26	4.99
Average	9.33	1.76	4.95

non-creeping habit of growth, which may or may not be desirable. Both of the Missouri strains, Saskatchewan, and Local appeared to be desirable types from the standpoint of low forage yield. The Jeanerett, Crotty, and SB-1 strains were desirable in that they displayed much greater vigor as seedling plants than any of the other strains. On the other hand, the Saskatchewan and Local strains made extremely slow early growth, the remaining strains being intermediate in that respect. However, as time went on, these differences tended to disappear.

The seedling vigor displayed by the Jeanerett, Crotty, and SB-1 strains is desirable in that it enables the plants to become established much more quickly thus making them more likely to escape injury by adverse conditions during the early stages of growth.

The differences between strains in the amount of foliage will be noted in Plate I. It is difficult to distinguish in the photograph between the dead and the living tissue but the differences between strains are easily recognized.

There was no apparent correlation between any of the characters listed in Table 1 and the percent of tissue killed or plants killed as determined by plotting the respective values on a graph. However, a rather strong correlation existed between the percent of plants killed and the percent of tissue killed. The latter correlation, however, would more or less be expected.

In Figure 2, the rather wide deviation of the Crotty and Wisconsin strains from the general curve established by the other strains will be noted. This would indicate that the Crotty strain can withstand greater tissue injury without destruction of the plants. On the other hand, indications are that only moderate damage to the tissue of the Wisconsin strain is likely to result in death of the plants.

In general the strains with the greatest differences in injury caused by the heat treatment could be recognized by observing all strains when placed side by side after they had been removed from the heat chamber. For example, in the first series of trials, the Madison, Wisconsin, strain was easily the most outstanding in its resistance to tissue injury. The Jeanerett, Crotty, H-14, Chas. Sweet, SB-1, and the Illinois, Orig. Kansas strains also showed considerable resistance to tissue injury. On the other hand it was not at all difficult to recognize the high degree of injury to the Saskatchewan, Local, Missouri Pg. 200, and Illinois, Orig. Canada strains. However, with the more intermediate strains it was impossible to distinguish any notable differences.

As shown in Table 2, there was only little variation in the respective ranking of the various strains as to the percent of tissue and percent of plants killed. It will also be noted that the same strains ranked among the upper seven in each case except the Crotty strain which ranked ninth in regard to percent of tissue killed and fourth as to percent of plants killed.

Table 2. Rank and average percent of plants killed and tissue killed in the first trial.

Strain	Plants killed		Tissue killed	
	Rank	Ave. percent	Rank	Ave. percent
Jeanerett	1	34.1	4	87.31
Chas. Sweet	2	38.3	3	86.92
H-14	3	40.8	2	86.76
Crotty	4	44.1	9	92.00
Madison, Wisconsin	5	45.9	1	81.15
Ill. Orig. Wash. Ks.	6	50.1	5	88.69
SB-1	7	51.1	5	88.69
Mo. Pg. 207	8	56.1	7	88.92
Saskatchewan	9	60.6	8	91.92
Ill. Orig. Canada	10	61.9	11	93.38
Local	11	63.6	12	94.92
Mo. Pg. 200	12	66.4	10	92.69

In the second series of tests the same general condition existed, that is the strains exhibiting the greatest differences could readily be recognized. The Chas. Sweet strain appeared to be injured less than any of the others and the SB-1, Crotty, and Illinois strains appeared to be injured more than the other strains. As shown by the average values for the percent of plants killed and the average percent of tissue killed in Table 3, it will be noted that considerable differences exist between the average values of some of the strains. There is a range of about twenty percent in the percent of tissue killed and thirty percent in the percent of plants killed.

Table 3. Showing the ranking and average percent of tissue and plants killed in the second trial.

Strain	Plants killed		Tissue killed	
	Rank	Ave. percent	Rank	Ave. percent
Chas. Sweet	1	10.0	1	67.3
Madison, Wisconsin	2	22.4	2	78.7
H-14	3	30.2	3	82.4
Ill. Orig. Kansas	4	38.0	4	84.0
Crotty	5	39.6	5	87.1
SB-1	6	40.0	6	87.6

The wide variations in the data and the visible differences between strains indicated that the variations between strains were great enough to be significant. A mathematical test of the data from the first series of trials showed highly significant differences among the strains in regard to the percent of tissue killed. It was determined that a difference of 2.13 percent between strains was necessary to be significant. Thus in Table 2 it will be seen that in the percent of tissue killed the Wisconsin strain is significantly better than all the others, the H-14 and Crotty strains are significantly better than Mo. Pg. 200 and those ranking below it, while Jeanerett is significantly better than the Saskatchewan strain and those ranking below it. It will also be noted that the strains ranking eight, nine, ten, eleven, and twelve are significantly poorer than all the other strains.

Table 4. Analysis of variance of the percent of tissue killed in the first series of tests.

Source of Variation	D. F.	Sum of Squares	Mean Square	F Value	1% Level
Between Strains	11	2040.75	185.52	4.20	2.39
Between Trials	12	12266.92	1022.24	23.15	2.32
Interaction	132	5826.92	44.14		
Total	155	20134.59			

Table 2 also shows the same general condition in regard to the percent of plants killed in the first series of tests. However, due to the frequent occurrence of zeros and one hundreds in the data regarding the percent of plants killed, it appeared advisable to transform the data. An analysis of variance of the transformed data showed the differences among strains to be highly significant with a difference of 4.85 percent between strains necessary for significance.

Table 5. Analysis of variance of the percent of plants killed in the first series of tests.

Source of Variation	D.F.	Sum of Squares	Mean Square	F Value	1% Level
Between Strains	11	8943.16	813.01	3.56	2.39
Between Trials	12	82916.86	6909.74	30.27	2.32
Interaction	132	30127.83	228.24		
Total	155	121987.85			

Table 2 shows that a considerable number of the strains are significantly better than others with a wide range between the best and the poorest.

The differences among the strains in the second series of tests were also found to be highly significant with a difference of 3.3 percent of tissue killed and 8.07 percent of plants killed necessary to be significant. Probably one of the first things to be noticed in Table 3 is that each strain has the same ranking in each of the two types of measurements, suggesting a high correlation between the percent of tissue killed and the percent of plants killed.

Table 6. Analysis of variance of the percent of tissue killed in the second series of tests.

Source of Variation	D.F.	Sum of Squares	Mean Square	F Value	1% Level
Between Strains	5	2845.09	569.02	16.49	3.45
Between Trials	9	3280.82	364.54	10.56	2.74
Interaction	45	1553.08	34.51		
Total	59	7678.99			

Table 7. Analysis of variance of the percent of plants killed in the second series of tests.

Source of Variation	D.F.	Sum of Squares	Mean Square	F Value	1% Level
Between Strains	5	3966.64	793.33	3.898	3.45
Between Trials	9	8778.28	975.36	4.793	2.74
Interaction	45	9156.50	203.48		
Total	59	21901.42			

In Tables 2 and 3 it will be observed that in both tests the Sweet strain was superior to the Wisconsin, H-14, Illinois, Orig. Kansas, Crotty, and SB-1 strains. The fact that the Sweet strain ranked first and the SB-1 strain last in two different tests is a

EXPLANATION OF PLATE I

Plate I shows typical appearances of the various strains after being subjected to high temperatures. The strains are, front row, left to right: H-14, SB-1, Crotty, Chas. Sweet, Jeanerett, Local, and Saskatchewan. Back row: Illinois, originally Canada; Illinois, originally Kansas; Pyramid, Svalof, Madison, Wisconsin; Mo. Pg. 207 and Mo. Pg. 200.

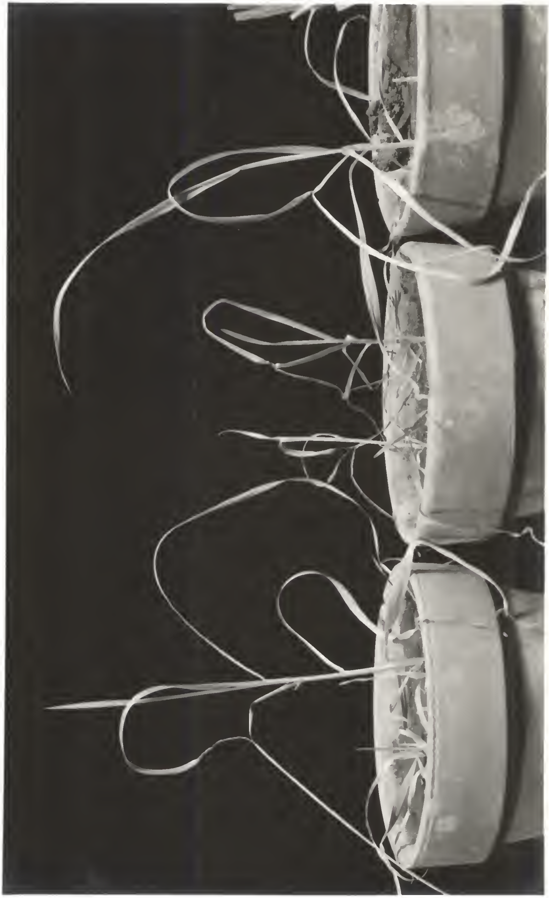
The strains labeled Pyramid and Svalof were included in the test but were later proved to be a different species; consequently, the data regarding their behavior was not included in the analysis of the data regarding the other strains.

PLATE I

EXPLANATION OF PLATE II

Plate II shows the effect of the high temperature treatment upon the plants when growth is resumed. Note how the tip of the flag leaf and the leaf which enclosed it are clasped together. This occurred in all strains.

PLATE II



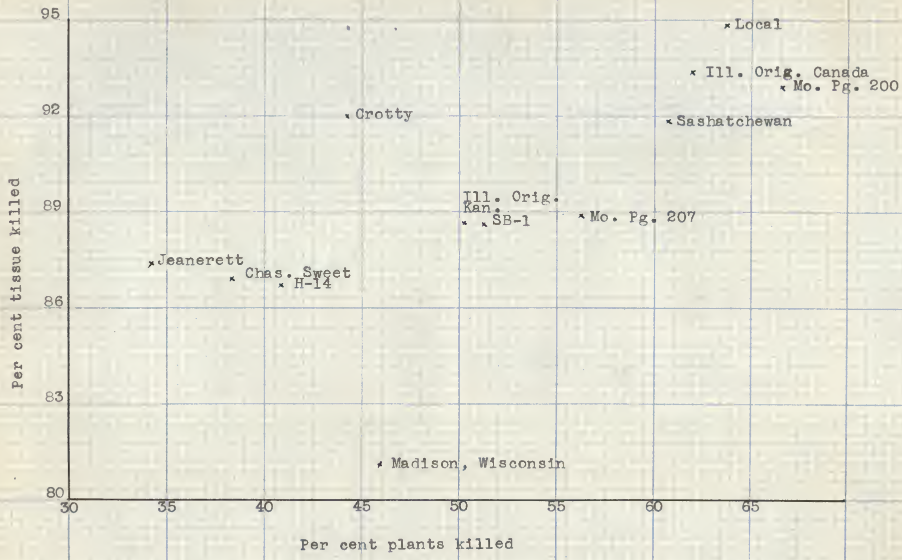


Fig. 2. Showing the relation between percent tissue killed and percent plants killed in the original test.

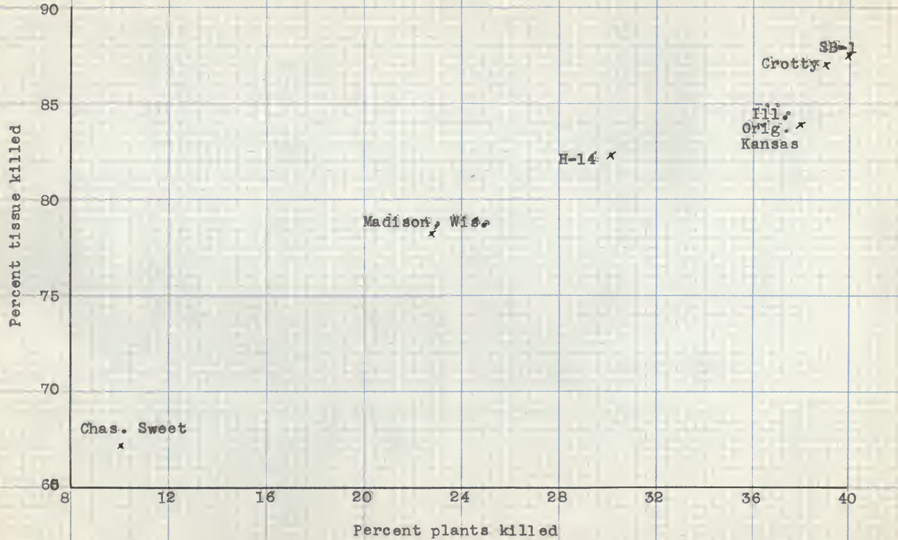


Fig. 3. Showing the relation between the percent of tissue killed and the percent of plants killed as determined in the second test. The strong correlation will be noted as well as the absence of any wide deviation by individual

strong indication that the Sweet strain actually is better than the other strains and that SB-1 is not quite as good as the others. Table 2 also reveals that all of the Kansas strains except "Local" ranked among the eight more resistant strains.

The wide spread in injury shown in Tables 2 and 3 substantiates the statement that strains having the greatest differences could easily be recognized and that no notable differences could be discerned in the intermediate strains.

From the results of the tests it would appear that a temperature control chamber can be successfully used to determine at least wide differences between strains of Bromus inermis in their resistance to high temperatures.

All of the strains used in the test, with the exception of the two Illinois strains, are being grown in the Kansas Agricultural Experiment Station grass observation nursery for observation under field conditions.

The fact is recognized that many more phases could and should be studied in connection with such a study as this. The observations presented in this paper in reality are just a beginning of an insight into some of the things that might be studied. It would be desirable to study such phases as the influence of time of day and light upon the resistance of brome grass plants to heat; the comparative resistance of seedlings and sod material of brome grass to drought; and a comparison of artificial drought tests with results obtained from field trials of the same material. Although field trials of drought resistance and other characters usually require several years for completion, it is necessary that a strain or variety of crop be grown under field conditions before it can be approved for distribution.

SUMMARY

A study was made to determine whether physiological differences in resistance to high temperatures exist among strains of *Bromus inermis Leyss* collected from various sources.

1. Highly significant differences in resistance to high temperatures were found among the strains tested.

2. The Kansas strains, Jeanerett, Chas. Sweet, Crotty, Local, H-14, and SB-1 with the exception of "Local," ranked among the more resistant ones.

3. The results obtained indicate that laboratory tests under controlled conditions may be used fairly successfully in determining the relative resistance of strains of *Bromus inermis* to high temperatures.

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