A METHOD FOR DETERMINING DROUGHT TOLERANCE IN CORN BY THE APPLICATION OF HIGH TEMPERATURE

By

JAMES WENDELL ECHOLS

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Oklahoma State University

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A METHOD FOR DETERMINING DROUGHT TOLERANCE

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OF HIGH TEMPERATURE

Thesis Approved:

James S Brooks

Thesis Adviser

John F Stone

Dale E. Weibel

J.H. Boggs

Dean of the Graduate School

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INTRODUCTION

Aamodt (1)[1] classified two kinds of drought, edaphic and atmospheric. Edaphic or soil drought prevails when the soil ceases to provide the plant with sufficient moisture to replace that lost by transpiration. The methods for testing plants for ability to withstand soil drought are comparatively simple. Atmospheric drought is caused by high temperature and hot, dry winds which may produce desiccation and killing of plant tissues even when moisture is adequate. The research in this thesis is primarily with atmospheric drought. Resistance to drought is usually defined as the ability of the plant to endure drought conditions and wilting.

Corn in Oklahoma has suffered from drought in most years grown. McCulloch (27) has stated the amount of soil moisture necessary for specific crops grown in most climatic areas of the United States. Areas with a climate similar to that in Oklahoma require 28 inches of soil moisture to produce maximum corn yields. During peak consumption periods, corn can consume .3 inches of soil moisture per day. Weather records[2] from 1937 to 1957 show Stillwater, Oklahoma, deficient in total moisture during the growing season of every year. June and July are usually the principal moisture consuming months. June has been deficient 14 of the 21 years while July has been deficient in 20 of 21 years.

1/Figures in parenthesis refer to "Selected Bibliography", page 59.

2/Unpublished weather records recorded by Oklahoma Agricultural Experiment Station Personnel, Stillwater, Oklahoma.

Drought has undoubtedly been largely responsible for the decrease in Oklahoma corn acreage from a maximum of 5,939,000[3/] acres in 1909 to approximately 200,000 in 1957. A comparison of weather records (40) and corn acreage often shows an acreage decline the year following a severe drought and an increase following a wet year.

The objectives of this study are to provide the plant breeder with basic information about the identification of drought resistance. The specific objective was to determine the techniques for evaluating strains of plants according to their drought resistance. The technique to eliminate susceptible plants in small, genetically variable populations could be effective.

3/A Statistical Handbook of Oklahoma Agriculture, Oklahoma Ag. Expt. Sta. Miscl. Publ. No. M. P. -14. January 1949.

REVIEW OF LITERATURE

Studies of Resistance or Susceptibility of Plants to Drought and High Temperature

Physiology and Anatomy

Weaver and Clements (41) describe a true xerophyte as having a reduced size of all cells, a thickened cell wall, a strongly developed palisade in the mesophyll, a dense network of veins, a large number of stomata per unit of area, high transpiration when water is plentiful, high osmotic pressure of the cell sap and a greatly increased capacity to endure permanent wilting.

Henkel (12) defined drought resistance in plants as that ability to adapt itself to dehydration and to over heating during phylogensis. Viscosity of the protoplasm is one of the chief factors responsible for heat resistance. In cereals, it increases from germination to the period of tuft formation and falls sharply during the phase of stem formation. Damage to plants usually brings about curtailment of its ability to synthesize foods and decomposition of protein.

Scarth (33) states that the maximum plasmolysis that cells can withstand is determined by the point at which an irreversible stiffening, presumably coagulation, of the ectoplasm occurs. Death of cells is probably caused by the rupture of the rigid ectoplasm when deplasmolysis occurs. Any greater resistance to coagulation, through dehydration, is due to greater water binding power of cell colloids.

Vassiliev and Vassiliev (39) made a study of the hardening of five varieties of wheat by severe wilting and bringing to recovery by irrigation. A series of chemical analyses of the cell content was made at the beginning of wilting, at permanent wilting, 24 hours after irrigation and eight days after recovery. Their results showed that monossaccharides and sucrose increased and hemicellulose decreased when wilting became apparent. During permanent wilting, sucrose decreased, monossaccharides increased and hemicellulose decidedly increased. After irrigation the water content increased and the soluble sugar content decreased but the water content was still below the control. Eight days after recovery, the water content still was lower than in the control but sucrose and hemicellulose had increased. They suggested that as the result of the hardening, the changed conditions seemed to be permanent. They also emphasized the importance of hemicellulose to drought resistance.

Tumanov and Trunov (37) found that hardened plant tissues contain more sugar and that plants can be hardened in the absence of photosynthesis as a result of absorption of sugar from an external source. Plant tissues could absorb sucrose in the amount of 10 to 12% of their wet weight. Winter rye which is more cold resistant absorbed sucrose more rapidly and accumulated a larger amount of sucrose than did less resistant winter wheat.

Newton and Martin (30), after studying the physical, chemical and physiological functions of various plants, listed the following factors as being influential in the drought resistance of plants:

A. Absorption

1. Soil factors
   (a) Amount of available moisture
   (b) Concentration of soil solution
   (c) Toxic substances in solution
   (d) Temperature
   (e) Aeration
2. Root development
   (a) Spread and depth of penetration
   (b) Intensiveness of branching
   (c) Number and persistance of root hairs
3. Physiological adaptation
   (a) Osmotic pressure of cell sap of root hairs
   (b) Imbibition pressure of hydrophylic colloids in cells
   (c) Mucilogenous secretions in region of root hairs

B. Transpiration
   1. Atmospheric factors
      (a) Temperature
      (b) Humidity
      (c) Air movements
      (d) Light intensity
      (e) Atmospheric pressure
   2. Structural factors
      (a) Ratio of root surface to leaf area
      (b) Conducting tissue
      (c) Rolling, folding or thickening of leaves
      (d) Decidious leaves
      (e) Epidermal coverings
      (f) Diminution of intercellular spaces
      (g) Sunken stomata
      (h) Stomatal regulation
      (i) Size and number of stomata
      (j) Surface hairs

C. Wilt endurance

Henkel (11) stated that drought resistance of plants is closely related to the colloid-chemical state of the protoplasm and the rate of metabolism. The ability of a plant to be dehydrated is dependent upon the elasticity of the protoplasm. The ability to endure overheating is related to higher hydrophil viscosity of the protoplasm, an increase in bound water and changes in metabolism such as respiration rate and fixation of ammonia.

Henkel further stated that soaking and drying of seeds before planting would permanently affect the elasticity of the protoplasm, the bound water content, the intensity of respiration, increase photosynthesis and enzyme activity and thus increase the drought resistance of plants. Soaking of swelled seeds in a .25% solution of calcium chloride caused a change in the metabolism and colloid-chemical property of the protoplasm and subsequently increased heat resistance.

Petinov and Molysheva (32) studied the effects of drought on corn by maintaining one treatment on soil irrigated to maintain an average moisture content of 70% of field capacity. Soil moisture in the drought treatment was gradually reduced from 40% to 30% of field capacity during the first half of the growing season and then reduced until plants reached the permanent wilting point. Drought caused a high increase in the respiration rate and the oxidative enzyme activity which was accompanied by a sharp decrease of assimalate flow out of the leaf. Incomplete oxidation of energy producing material was responsible for decrease in metabolic process.

Wiebe (42) noted that as plants wilt the stomata close and thus greatly reduce transpiration. This permits survival but greatly reduces photosynthesis because of the reduced quantity of carbon dioxide that can enter the plant. Wilting reduces cell growth and turgor pressure decreases until it is too low to hold leaves erect. This reduced turgor pressure causes a reduction in the translocation of nutrients. This was studied by observing the movement of $carbon_{14}$ in wilted and normal plants. Leaves of wilted and normal plants were enclosed in plastic containers and carbon dioxide containing $carbon_{14}$ was injected into the containers. After several hours plants were pressed, dried and placed in contact with photographic film. All portions of the normal plants exposed the film while the wilted plants exposed only the leaves that were enclosed in the plastic containers. The same measurements were also determined with a Geiger counter.

Iljin (17) stated that plants growing in a dry habitat contain more sugar. A group of succulent plants contained an average dry weight sugar content of 0.72%, herbaceous mesophytes 1.25%, herbaceous xerophytes 2.64%, mesophytic trees and shrubs 3.60% and xerophytic trees and shrubs 6.89%.

Xerophytes consume a smaller quantity of organic substances in respiration than do mesophytes. A group of xerophytes lost an amount of sugar equal to 4.0 to 9.0% of their dry weight by respiration during a 24-hour period while mesophytes consumed sugar in the amount of 7.7 to 15.4% of their dry weight in a 24-hour period.

A comparison of fresh and wilted plants showed a marked difference in photosynthetic rate. A 20% decrease in the photosynthetic rate of plants occurred after a water loss of 16 to 47%. Plants which have recovered from wilting have a reduced assimilation capacity ranging from 35 to 59% of plants which have not wilted.

The principal factors responsible for the death of cells subjected to desiccation are the structure of the cells and the presence of a large vacuole in each cell. When cells are large and vacuoles are correspondingly large, cytoplasmic membranes are delicate and thus drought causes a rapid destruction of the cell.

Buds of higher plants are very resistant to drought. Their cells are quite devoid of vacuoles but as growth and development occur, vacuoles are formed and simultaneously resistance to drought decreases. Germinated seedlings behave in a similar manner.

Asana (3) studied the effect of drought on characters directly related to yield in wheat and found that drought reduced the grain number per head and the 1,000-grain weight. If plants suffered from early drought, grain number was reduced but later drought affected the weight per head and the 1,000-grain weight. During the first four weeks after dehiscence, leaves and stems yellowed more quickly under drought but the head remained green and a considerable amount of sugar was transported to the head from the stem. After this time approximately ten per cent of the grain weight was the result of translocation of sugar from the stem. Photosynthesis in the head apparently accounted for a considerable amount of the grain weight in the later stages of maturity.

Jenkins (18) found that in a number of inbred lines and crosses of corn there was a marked difference in resistance to leaf burning associated with hot dry weather. Ten crosses that were the progeny of one line were completely free from leaf burning whereas those of another line ranged from some to many burned leaves among the different crosses. This variation indicated that progress could be made by further physiological and genetic investigations.

Martin (26), in comparing the drought resistance of sorghums and corn, found that sorghum had a higher osmotic concentration of the sap in the stalk, crown and roots, but had a lower osmotic concentration in the leaves. Sorghum was found to have a lower transpiration ratio under conditions of high evaporation and wilted less rapidly.

Holbert and Frye (15) concluded that the bound water content of leaf tissue was a good indication of the relative drought resistance of strains of corn. Total free and bound water determinations were made in the period from July 17 to August 3, 1932. Temperatures ranged from 95 to 103°F. These determinations indicated that in heat-resistant strains of yellow-dent corn, water binding capacity of leaf tissue increased as heat and drought continued. From July 19 to 26, total water content decreased 5.4% and bound water increased 62.1% (wet basis) or 35.2% (dry basis). On the second day after a 1/2-inch rain, there was another marked shift in bound water and free water equilibria in the direction of conditions existing prior to the heat and drought period. Total water content increased 1% and bound water decreased 23.2% (wet basis) or 21.5% (dry basis).

Water binding capacity of comparable leaf tissues of heat-susceptible strains increased very little as heat and drought continued and in some strains decreased significantly. During the first three days after the heat and drought period had passed, heat-susceptible strains made phenomenal growth. Their water binding capacity increased rapidly and almost equaled that of heat-resistant strains. Prehardening for heat as well as for cold has shown marked increases in water binding capacity.

Haber (9) studied pure lines of sweet corn, which had been classified as drought- and heat-susceptible or resistant, to determine if certain anatomical or physical characters were correlated with resistance or susceptibility. The transpiration rate of inbred lines of sweet corn was higher with susceptible inbreds as a group than with resistant lines under conditions of high temperature and low relative humidity. This could not be used as a basic classification because the difference was not of sufficient magnitude and variations were found within the susceptible and resistant groups. No significant differences in the number of stomata of the leaves of resistant and susceptible inbred lines were obtained.

The volume of roots may account for susceptibility of several lines, but no significant differences occurred between the weights of roots of the two classes when grouped together. Haber reported that a pure line of corn isolated by Dr. M. T. Jenkins called rootless had a root system so poor that it would not support the plants in an upright position. However, it was among the most resistant strains when drought ratings were taken. The number of nodes below the surface of the soil did not differ when the two classes were averaged.

The total number of vascular bundles in the stalk depended upon the diameter of the stalk. The average number of bundles per unit area was a better comparison but the resistant and susceptible classes did not differ significantly in this respect. A comparison of a limited number of resistant and susceptible inbred field corn lines showed a significant difference between strains. No correlation was found between seminal root growth and drought resistance but it appeared that there was an association between crown root development and drought resistance. There was a high association between secondary root development (fibrous roots) and drought resistance. The resistant strain had the ability to produce more secondary roots than the other two strains in an increasing water deficit. As the stress continued, the susceptible strain ceased producing secondary roots.

Brooks (5) reported several types of top firing observed in the corn breeding nursery in Kansas, each being characteristic of certain inbred lines. The most common type started at the tip of the leaf with a progressive extension downward on the margins, followed by firing of the portion between the margins. If conditions were severe, this type progressed until the entire leaf had fired. Another type was the firing of the tip and portion along the midrib before the margins were damaged. Sometimes injury occurred in spots or streaks along the midrib. It also occurred in a belt across the blade. It appeared that this belt was the portion of the blade which received the greatest amount of direct sunlight. Most firing became severe at about tassel time.

Brooks also studied the movement of eosin dye through the conducting tissue of leaves from plants resistant to firing and from plants susceptible to firing. Leaves were removed and the disected portion of the leaf placed in the dye at the tassel stage of growth. Remarkable differences in the movement of the dye were observed. When the leaves were cut at the base of the sheath, the dye rose much more rapidly in the resistant line K148 than in the susceptible line CI7. When the leaves were cut through mature tissue above the collar, the veins of the susceptible line CI7 showed a much greater rise of the dye. In all comparisons made with cuts below the collar, there was greater movement in resistant than in susceptible lines.

Skold (35) recorded per cent firing and obtained yield data of all varieties entered in the Kansas Corn Performance Tests in 1939. Varieties were tested at each of the five experimental districts of Kansas. In four of the districts, there was a positive correlation coefficient significant at the 1% level between firing and yield.

Variations in Water Economy

Kiesselbach (20) found a definite relationship between heterozygosity and the water requirement of corn. Selfed lines, which had been reduced in size and productivity by inbreeding, had materially higher water requirement ratios than either F_1 hybrids or the original varieties from which they were developed. Great variability was visible among F_1 hybrids in water requirement ratios and total water transpired per plant.

Misra (29) studied edaphic drought in four varieties of wheat and four strains of hybrid corn. Plants were grown in 6-inch clay pots and severity of drought was controlled by the amount of water added. The four varieties of corn were subjected to 15 days without water at 2, 3, 4 and 6 weeks of age. After the drought period, plants were watered and information recorded as per cent survival. At two weeks of age varieties ranged from 79.2 to 54.2% survival, three weeks 75.7 to 22.2%, four weeks 64.1 to 21.7% and six weeks 42.5 to 7.9%. Comparisons showed K2234 first in all tests, K1639 second in all tests, K1784 third in the three older tests and fourth in the two-weeks tests, and K1830 the poorest in three tests and third in one test.

By using a hardening process consisting of allowing the plants to grow with a scanty water supply, great variation was shown between hardened and non-hardened plants. Percentage recovery was far greater for hardened plants and variation increased as plants became older. Varietal differences in susceptibility were maintained throughout the hardening process. The study with wheat gave similar results.

Kydrea (22) found that by soaking and drying wheat seeds, cold tolerance could be increased. When plants in third leaf stage were treated with temperatures of -16°C. for 24 hours only 2.4% of plants from untreated seeds survived. Plants from seeds soaked six hours and dried had 12.75% survival, incipient germination and dried 25.20% survival, germination until first root formed and dried 15.20% survival.

Zubenko (43) found that by soaking corn seeds for 24 hours and drying

24 hours, emergence was 111% and grain yield under droughty conditions 128% of the check plot. By soaking and drying corn seeds for two stages of 24 hours each, emergence was 122% and grain yield was 140% of check plot.

Tyurina (38) stated that drought and frost resistance is related to free and bound water content of plants. He collected leaves from several species of plants. Leaves were placed in a stream of air at 10 to 15°C. for several minutes to several hours and water loss determined by weight. Water retaining force of leaves was also measured by submersion in sucrose solutions of various concentrations. Solution in which neither absorption nor output of water occurred characterized water retaining ability. Both methods of measuring moisture holding capacity detected considerable differences in plants. Xerophytic species had considerably more moisture retaining ability.

Heat Chamber Studies

Due to uncontrollable environmental factors associated with field growing conditions, it is difficult to obtain valid information about drought resistance unless many years of field ratings can be recorded. To supplement this information, some researchers have used heat chambers to study atmospheric drought.

Aamodt (1) constructed a glass chamber with a capacity of 40 to 50 six-inch clay pots. Air, which had been preheated by thermostatically controlled electric heaters, could be forced through the chamber at a controllable velocity. After exposing plants for 8 to 15 hours at 110°F., relative humidity 14% and an air velocity of six miles per hour, the desired results were produced. Wheat varieties known to be drought resistant in the field showed less injury than varieties known to be non-resistant.

Aamodt constructed this chamber by using information received in correspondence from Dr. T. Maximov of the Institute of Applied Botany and

Plant Breeding, Leningrad, Russia.

Hunter et al (16) used a control chamber 5 x 5 and 8 feet tall with temperature and humidity controlled automatically. Corn plants were grown in 4-inch unglazed pots and thinned to a uniform stand. By testing at 140°F., relative humidity approximately 30% and a duration of 6.5 hours, it was possible to distinguish among strains with respect to drought resistance. Essentially the same order of relative resistance was obtained with the seedlings as was noted for the plants observed in the field during drought years.

Plants in the field were rated Resistant, Top Firing or Base Firing. The lines susceptible to top firing under field conditions showed marked injury in the testing chamber within three to five hours. Lines susceptible to base firing showed injury in four to six hours and the lines classified resistant showed little or no injury after 6.5 hours. When these plants were returned to good growing conditions, the survival of plants was 0% in the lines susceptible to base firing, 0 to 25% in those susceptible to top firing and 50 to 100% for the resistant lines.

Heyne and Laude (14) attempted to duplicate the results of Hunter et al (16) by using the same heat chamber and environmental conditions except 20-day old plants instead of 14-day old plants. All of the 20-day old plants were killed in 6.5 hours.

A study was made of stored food reserves in the seed at various intervals after planting, to learn if the amount of reserves might be associated with heat resistance. The decline in weight of seeds was rapid during the first 10 days of growth, being only 32% of the original weight. It continued to decline slightly to about 15% on the 18th day with no change thereafter. Correlation between damage to plants and per cent original weight of seed was close. No correlation was found between kernel size and heat tolerance.

Heyne and Laude concluded that the best results, for determining drought resistance of field corn, were obtained when the plants were 20 days old. The best temperature was 130°F. for a duration of five hours. Haber (9), using sweet corn lines in a different chamber, found that most lines were killed within five hours at 131°F. No sweet corn lines would withstand severe temperatures as well as field corn lines classified resistant.

Heyne and Laude (14) found striking differences when plants were subjected to high temperature in early morning and in afternoon. Plants placed in a dark room prior to treatment exhibited far less resistance than plants which had received sunlight. Dexter (7) has shown that sunlight has a definite effect on the hardening of wheat plants to low temperatures. Plants deprived of carbon dioxide would not harden under any circumstance which shows that photosynthesis was involved in hardening plants.

Finkner (8), using wheat plants with the same heat chamber that Hunter used, has shown that the greatest increase in the hardening effect of sunlight was during the first hour of exposure. There was a gradual increase in hardening until plants had received two hours of sunlight. Exposures beyond two hours produced no measurable effect. Plants, placed in a specially devised chamber which eliminated carbon dioxide but permitted sunlight, reacted to high temperature in a similar manner as did plants kept in darkness preceding the heat treatment.

Metcalfe (28) studied the hardening of plants using pretreatments of varying intensities of light, moderately high temperature, moderately low temperature and a limited amount of soil moisture. Three intensities of sunlight, three intensities of artificial light and darkness as a check gave significant correlations between heat chamber damage and light intensity. Dark pretreatments had 83% damage while the greatest light intensity had only 11% damage.

Plants subjected to pretreatments of 100 and 110°F. for three hours per day, continuously developed hardiness. The 110°F. pretreatments were slightly more effective than 100°F. pretreatments. This hardiness was lost within 12 to 14 days after treatment. Plants not watered after five days from emergence but watered and placed in the heat chamber at 15 days of age were more resistant than plants watered daily. Plants subjected to pretreatment of 34 to 40°F. also appeared to be more resistant than the check but did not exhibit as much resistance as the other pretreatments. The hardening produced the same effects on sorghum and wheat as it did with corn.

Hague (10) studied three strains of corn classified as Resistant, Intermediate and Susceptible to heat damage. The most resistant strain and the most susceptible strain at three weeks of age, remained in their respective positions at six and nine weeks of age when placed in the heat chamber and then allowed a favorable period for recovery. The variation between strains was less as plants neared maturity.

Skold (35) compared field firing and heat chamber damage using four inbred lines and their progenies. From these inbreds, four single crosses were made and back crossed to each parent, giving a total of four inbreds, four single crosses and eight back crosses for comparison. Field firing of the inbreds ranged from 18 to 28%, the single crosses 20 to 36% and back crosses 22 to 30%. Damage ratings from heat chamber studies ranged from 54 to 76% for inbreds, 61 to 74% for single crosses and 50 to 68% for back crosses. There appeared to be a similarity between field firing percentage and heat chamber damage but correlation was not significant.

Chen (6) made studies of heat chamber damage and the effects of a deficient soil moisture supply using five strains of grain sorghum grown in the greenhouse. Heat chamber studies were conducted at three stages of growth and two light conditions prior to treatment. All strains were the most resistant to heat chamber damage at nine to ten days after planting. There were only slight variations between 18- to 19-day old plants and 25- to 26-day old plants. All morning treatments were more susceptible to heat chamber damage than afternoon treatments.

Blackhull kafir was the most resistant in all tests and Dwarf Yellow milo was second. The third strain proved superior to the remaining two, which showed no difference and the most susceptibility. When the same strains were grown under deficient moisture conditions, Blackhull kafir and Dwarf Yellow milo were reversed in the order of resistance. One of the most susceptible strains in the heat chamber test ranked third in the deficiency test.

By making heat chamber studies, Patterson (31) found wide differences in heat resistance in pure strains of bromegrass. Highly significant differences were obtained when progeny groups of the previously tested inbreds were compared after high temperature treatments. There were good indications that lines surviving heat treatments agreed with strains surviving the Kansas drought of the 1930's.

Levitt et al (25) drought-hardened plants by watering when severely wilted for periods of two to six weeks. Drought tolerance of hardened plants was then measured by placing sections of plants in various relative humidities until 50% killing of cells occurred. Plants known to be adapted to drought failed to undergo any detectable increase in drought tolerance but plants not considered to be xerophytic showed a significant increase in tolerance.

They also measured drought resistance by placing shoots of different plants in a heat chamber with a relative humidity of 15% and a temperature of 30^{o}C. Seedlings were removed from soil, cut at the base underwater, and the base of shoots kept underwater in the chamber until 50% injury occurred. Shoots from an _Oxalis sp._ were injured in five to six hours, tomatoes 11 hours, barley 24 hours, sunflower 31 to 34 hours and _Setcreasea striata_ 32 days.

<u>Genetic Studies with Corn</u>

The inheritance of drought resistance in corn undoubtedly involves many genetic factors. Many of these factors are probably complementary and thus poorly understood.

Brooks (5) studied the inheritance of resistance or susceptibility of inbred lines by making a series of crosses and back crosses using parents classified as resistant or susceptible. Plants were evaluated by the amount of damage from heat chamber tests. Comparisons indicated that resistance to drought is dominant or partially dominant in some crosses but complementary in others. Heyne and Brunson (13) found that drought resistance was definitely inherited and in most cases was intermediate to dominant. Hybrid vigor apparently did not make a cross resistant to drought, at least in the seedling stage.

Heyne and Brunson (13) obtained 27 lines of corn which carried genes marking the ten chromosomes, ten translocation stock lines and four susceptible sweet corn lines to be used as test cross parents. The most resistant and the most susceptible lines obtainable were used as parental material. Plants were evaluated by the use of a heat chamber.

Linkage relations were studied between one or more genes and the possible factors determining heat tolerance in eight of the ten linkage groups. Close association of heat tolerance with Su_1 su_1 (chromosome 4), Prpr (chromosome 5) and a possible association with Cc (chromosome 9) was observed. The effects of gl and gl_2 (chromosome 2) apparently protected the seedling while the factor gl_2 probably did not possess this protective quality. The su gene was considered to be directly responsible for susceptibility as shown by the behavior of seedlings from sugary and starchy kernels. The chromosome four translocation study gave an equal distribution of semisterile and normal plants among those tolerant to heat when a back cross was used. This indicated that no gene other than su was responsible for this tolerance.

Arnakis (2) used translocation stocks, involved in all of the ten chromosomes except number seven. An attempt was made to locate genes affecting field firing in susceptible inbred lines La 44 and CI 7. Translocated plants, determined by examination of pollen cells, were classified as fired or non-fired. Indications were that the gene or genes affecting the top firing character in La 44 were located either on the long arm of chomosome one, on the short arm of chomosome four or on both. It was suggested that genes closely linked to the sugary (Su) gene, were responsible for this susceptibility if chromosome four was the one carrying the gene. The genes affecting the base firing character in CI 7 could be located on chromosome two, four, ten or any combination of these chromosomes.

The susceptible inbred La 44 seemed to be more prepotent than CI 7 in transmitting top firing when used as a recurrent parent with the cross La 44 x CI 7. The distribution of the selfed progenies from the back cross (La 44 x CI 7) x La 44 indicated the action of at least two pairs of major genes for susceptibility. The F_3 data from the cross CI 7 x La 44 indicated that these genes might be different in each of these inbreds and might be complementary in their action. Some indication of the action of complementary genes for susceptibility was found when susceptible CI 7 was crossed with moderately resistant inbreds 38-11, K10 and K155.

MATERIALS AND METHODS

Design and Construction of the Heat Chamber

The heat chamber used in this study was essentially a large box constructed from number ten gauge sheet metal. It was 2 1/2 feet wide, 6 1/2 feet long and 3 feet high. The pieces of metal were fastened together with steel screws and electrically spot welded to get the maximum rigidity from the box-type structure. Points of stress were strengthened by using two thicknesses of metal. A stand was constructed from 1 1/2-inch angle iron to get the chamber to the most convenient height. Two hinged doors, 18 inches by 24 inches, were used on the side of the box to make accessible openings. The doors were constructed from heavier sheet metal with heat-resistant, glass windows.

The box was insulated by completely covering the outside area with 3/4-inch asphalt coated fiberglass excluding the doors. The doors were painted with a heat-resistant insulating material to reduce the amount of heat lost by conduction and radiation.

The chamber was heated by an upright, steam-heated radiator. Steam pressure could be regulated by a hand-operated valve and the steam could be turned on or off by a thermostatically-controlled radiator valve.[1/] The honeycomb-type circulating surface of the radiator was 10 1/2 inches by 11 1/2 inches. Air was forced through this radiator and through the chamber by an electrically driven, four-bladed fan which was eight inches in diameter. The blades had 32^{o} pitch and a maximum speed of 1550 RPM. Two slower speeds

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1/Electric Radiator Valve V605A61K4, Minneapolis-Honeywell Regulator Company, Minneapolis, Minnesota.

could be obtained by the use of a three-speed resistor type control switch.

The expansion unit of the thermostat was located in the center of the chamber and could be raised or lowered to any desired height. A height of approximately 10 inches above the bottom of the chamber proved to be the most desirable. The control unit of the thermostat[2/] could be easily adjusted to regulate the temperature within the chamber at any range between 80 and 175°F. It would control the fan motor, radiator valve or both. When the radiator valve was opened by the thermostat, it took several minutes for the radiator to become warm enough to produce the desired heating. It took even longer for the radiator to cool sufficiently when the valve closed. All experiments were conducted with steam in the radiator at all times and the fan controlled by the thermostat. A temperature drop of approximately 5°F. occurred between the time the fan was switched off until it was turned on again. The most sensitive thermostat obtainable should be used in any future heat chamber construction.

Two 72-inch, 73-watt florescent lights were mounted on the ceiling of the chamber. These lights were placed in the chamber so that visual observations could be made while the chamber was in operation. It was also desired to learn what effect these lights would have on the resistance of the plants during treatments.

A water-tight pan, the size of the inside of the chamber and 5 inches deep, was placed on the bottom of the chamber. A faucet was affixed to the bottom of the pan for easy draining. This pan was constructed to provide continuous soil moisture for the plants if desired, but it was not necessary to use additional water in any of the experiments conducted.

2/Electric Thermostat T415A351XA3, Minneapolis-Honeywell Regulator Company, Minneapolis, Minnesota.

The steam-heated radiator was attached to the end of the box and was mounted so all the air was forced into the chamber. Sliding regulator doors were arranged at the end opposite the radiator and on one side of the box to control the flow of air through the chamber to produce a wind tunnel effect, as described by Aamodt (1). This proved ineffective due to temperature variation in various parts of the chamber.

The entire circulatory system was redesigned to reduce temperature variation within the chamber. The steam radiator was removed from the end of the box and mounted with the bottom of the radiator approximately 18 inches above the top of the box. The radiator was centered to the length of the box and mounted about 6 inches beyond the side opposite the doors. The end of the box, where the radiator was previously mounted, was completely closed and all sliding doors sealed air tight.

Sheet metal duct pipe was constructed to convey the fan-driven air from the radiator to flume pipes connected to the top of the chamber. This duct pipe was the exact size of the circulatory surface (10 1/2 x 11 1/2 inches) of the radiator. It extended horizontally from the radiator and then made a 90 degree downward turn to a point about 8 inches above the roof of the box. The end of the duct pipe was sealed air tight. A trap door was constructed inside the duct to permit fan-driven air to flow through the duct but to reduce convection currents when the thermostat turned off the fan.

Flume pipes, 7 inches in diameter, were affixed equilaterally to two sides of the duct pipe to get an equal division of air through each flume. The flumes left the duct pipe at about a 45 degree angle. They extended outward and downward to points centered in the width of the roof and equidistant to the exact center of the roof and the ends of the box. At these points the flumes turned straight down and entered the chamber at 90 degree angles to the roof. This gave each flume exactly half of the chamber for heating.

An artificial roof, the exact size of the inside length and width of the chamber, was cut from fiberboard to serve as a baffel for the air delivered by the two flumes. Holes, 3/4 inch in diameter, were drilled at 3-inch intervals in the fiberboard both lengthwise and crosswise. This gave a total of 225 holes spaced equally over the entire fiberboard. The baffel was mounted in a horizontal position near the top of the chamber. It could be set at any height between 3 and 9 inches from the roof of the chamber. Approximately 6 inches from the roof proved to be the most desirable height. Small pieces of heat-resistant tape could be placed over any of the holes to obtain the desired distribution of air through the baffel. Before installation of the baffel, the flourescent lights were mounted on the sides of the chamber near the baffel.

Holes, 3/4 inches in diameter, were drilled at 4-inch intervals around the entire perimeter of the chamber 5 inches above the bottom of the chamber. The fan-driven air circulated from the flume pipes, through the holes in the baffel and out the holes near the bottom of the chamber. The velocity of the air current was not measured, but it created only slight leaf movements when plants were in the chamber. Thermometers were placed at various points within the chamber. After regulating the flow of air through the baffel with strips of heat-resistant tape, the temperature varied less than 1^{o}F. at any horizontal level within the chamber. There was some temperature variation vertically, with temperatures progressively higher from bottom to top of the chamber.

No attempt was made to control humidity. Hygrothermograph readings showed very little relative humidity variation at high temperatures. Relative humidity was 11 to 14% at 140^{o}F. and slightly higher at lower temperatures.

Growing of Plants

All plants in this experiment were grown in wooden flats 20 inches long, 14 inches wide and 3 inches deep. "Vita-Bands"[1/] (asphaltic paper bands) were 2 1/2 inches by 2 1/2 inches and 3 inches tall. Forty bands were placed in each flat in eight rows with five bands in each row. Flats were filled with uniform sandy loam soil obtained from Field No. 31, Oklahoma State University Agronomy Farm located one mile west of Stillwater, Oklahoma. Soil was screened through 1/4-inch hardware cloth and air dried prior to the time flats were filled.

Seed was obtained from the Agronomy Department, Oklahoma State University, Stillwater, Oklahoma. Seed lists are as follows:

Hybrids

1. Oklahoma 301
2. Oklahoma 1815 (ex)
3. Kansas 2234
4. Kansas 1859
5. Texas 30
6. U. S. 13
7. North Carolina 1032

Open-Pollinated Varieties

1. Woods Corn 113
2. Yellow Surecropper 119
3. Pride of Kansas 140
4. Mexican June 146
5. Oklahoma White Wonder 153
6. White Pencil Cob 154
7. Roley White 172
8. Mass Selection Variety 184

Single Crosses

1. OK 22 x OK 19

Inbreds

1. 38-11
2. 77 C
3. 116-0-126-3-1-2-1-2
4. 116-0-126-3-1-2-1-3
5. 116-0-126-3-1-2-2-3
6. 116-0-126-3-1-2-2-4

1/Vita-Band is the trade name of a product sold by Bird and Son, Inc., East Walpole, Massachusetts.

7. 119-2-2-1-3-1
8. CI 7
9. CI 21E
10. Hy
11. K-4
12. K 159
13. Ky 106
14. N.C. 88
15. OK 11
16. OK 12
17. OK 15
18. RYD 11-117-3-1
19. RYD 11-117-3-4
20. RYD 11-118-1-1

Seeds were planted approximately 1 inch deep in the air-dry soil of each vita-band. The use of air-dry soil permitted the planting of several flats when additional help was available except flats in which more than one age group was desired. The soil was dry enough that no seeds absorbed any visible amounts of moisture. The germination and growth of plants was controlled by watering the planted flats at the desired time. Additional water was added when the soil dried to a depth of 1/4 to 1/2 inch.

Plants began to emerge four to five days after watering. The majority of the plants had emerged by seven days. It was very rare for any seedlings to emerge after nine days. Emergence counts from the first flats planted indicated that there were greenhouse position effects.

Racks for the flats were constructed so that all flats were approximately 8 inches above the floor of the greenhouse. This permitted air to circulate on all sides of the flats and reduced variation of emergence time and growth. It also simplified planting, watering, and rotating of flats.

There were slight differences in emergence times among varieties, but never more than one day. There was continuously some variation in emergence time among flats first watered on different days. Average daily greenhouse temperatures varied from 74.0 to 88.5^{o}F. It appeared that temperature variation was directly responsible for most variation of emergence time; however, this variation was never in excess of one day.

With the first plantings only one seed per vita-band was planted and extra flats were planted from the same seed source. It was planned to transplant seedlings to obtain 100% stand in each flat. This proved unsatisfactory because roots reached the bottom of the flats so quickly that they would become entangled with roots of other plants before they could be transplanted. Transplanting did not cause any visible damage to the growth of plants but it was discontinued. In all subsequent plants, two seeds per band were planted and thinning to one plant per band was accomplished ten days after planting.

Greenhouse growing conditions appeared to be very favorable for corn. Plants were measured by two methods, to the top of the whorl and to the tip of the longest leaf. Fifteen days after watering the soil, the more vigorous plants had grown to 6 inches high at the whorl and 16 inches to the top of the longest leaf. By 22 days from watering of the soil, the more vigorous plants had grown to 10 inches at the whorl and 30 inches to the top of the longest leaf. Throughout the remainder of this paper, age of plants shall be the number of days after planted flats were first watered.

Experimental Designs and Procedures

All experiments in this study were designed so that they could be statistically analyzed by methods described by Snedecor (36). Five main experiments, subjecting growing corn plants to high temperatures were conducted. Experiments conducted are as follows:

1. The comparison of eight genetically variable open-pollinated varieties.

2. The comparison of six commercial hybrids, one experimental hybrid, and one open-pollinated variety.

3. The comparison of 20 inbred lines believed to have some variation in their genetic ability to withstand high temperature.

4. A study to determine the effects of high temperature on plants of five ages using two light conditions, five different temperatures, and four different positions within the heat chamber on one hybrid. It was also desired to know the interaction, if any, of these four variables.

5. A study to determine the effects of high temperature on plants of three ages, two light conditions, three temperatures, and the four position effects on one hybrid, one signle cross, one open-pollinated variety and one inbred line.

In all experiments conducted, seeds were planted and seedlings thinned to obtain either five plants or eight plants per row. The open-pollinated variety comparison consisted of 12 flats with five plants of each of the eight varieties planted in random rows. Each flat was called a replication and the results from 12 flats were analyzed as a randomized block. The hybrid comparison was conducted in the exact same manner except 20 flats of plants were analyzed as a randomized block.

The 20 inbred lines were assigned random numbers and divided into four groups of five lines each. Each group was planted in a flat in five randomly selected rows with eight plants in each row. The four groups were combined to make one replication or run in the heat chamber. It was originally planned to place each of the groups in all four of the positions in the chamber and analyze group results as a latin square. A mistake in flat placement prevented this analysis. It was analyzed as a randomized block with a total of four replications.

The age, light, and temperature study was conducted using Oklahoma 301 hybrid because it was one of the more resistant varieties in the hybrid test. Seeds were planted in each flat with eight plants in each of the five rows. Planting dates for each row were staggered at two-day intervals to obtain five randomly arranged age rows in each flat. Age of plants ranged from 15 to 23 days at treatment time.

A total of 40 flats were planted at the proper intervals to give two heat chamber runs (four flats per run) per day for five days. All flats contained the same five ages of plants at the time of treatment. Two light conditions were used each day by placing four flats in the chamber prior to daylight and placing the other four flats in the chamber after the plants had been exposed to a minimum of six hours of daylight. The two groups of plants treated each day were subjected to the exact same temperature. The first temperature treatments were 120°F. and each following day the temperature was increased 5°F. to the highest temperature of 140°F. the final day.

Records were kept on the flats for each of the four positions within the heat chamber. There were ten runs or treatments and the information from these treatments was analyzed as a 2 X 5 X 5 factorial arrangement in a randomized block.

The age, light, temperature, and genetic variation study was conducted using Oklahoma 301 hybrid, OK 22 x OK 19 single cross, Yellow Surecropper 119 open pollinated, and OK 15 inbred. Each variety was planted in two rows of five plants each in all flats used in the experiment. Two plantings of the four varieties were made at two-day intervals, giving a total of ten plants of each variety per flat. Plantings were scheduled so that the plants would be 21 and 23 days of age in three runs, 19 and 21 days of age in one run, and 23 and 25 days of age in one run. One run of the 21 and 23 day old plants was started before daylight. All other runs were started after plants had received at least six hours of sunlight.

The information from this experiment was analyzed as a 2 X 4 X 5 factorial arrangement in a randomized block. Ages were classified as young and old, and no consideration was given to the light conditions in this analysis. Further analyses for genetic and age variations were conducted using each of the separate runs as a separate experiment composed of four replications and by combining information from some of the runs to obtain eight replications.

Operation of Heat Chamber and Treatment of Plants with High Temperature

The most successful method of getting the desired temperature was obtained by heating the chamber prior to use. For preheating, four flats filled with soil were placed in the chamber in the exact same manner as the flats with growing plants. Flats were placed on a rack 4 inches above the floor of the chamber. This permitted air to circulate on all sides of the flats and reduce the temperature variation near the flats. Identical thermometers were suspended above each flat with the base of the thermometers 6 inches above the flats. The thermostat-control unit was set for the desired temperature. After the heating unit had operated long enough for the temperature to become stable, the control unit of the thermostat was adjusted until the thermometers were at the desired point when the thermostat would stop the fan. One hour's operation time was usually required to stabilize the temperature. Thermostat adjustments were repeated until the cut-off temperature did not change from the desired reading.

All flats were watered to field capacity or above just prior to the time they were placed in the chamber. This was done as an attempt to give each plant an equal amount of soil moisture.

Six hours seemed to be the optimum duration for treatment. Periods longer than six hours produced the same comparative results although some of the soil appeared to be getting dry and thus offering the possibility of variation due to the amount of moisture in the soil. Treatments of less than six hours appeared to cause more variation for a particular variable. Visual observation of the plants can be used to determine whether the plants are ready to be removed from the chamber. Immediately after treatment, plants were watered and returned to the area of the greenhouse where they had grown.

<u>Scoring and Rating of Plants</u>

Scoring systems were established to be as simple and rapid as possible. The numerical system was used so that information could be analyzed statistically. The following system was used for evaluating each plant of the open-pollinated, hybrid, and inbred tests:

1. Less than 25% of leaf tissue damaged.

2. Leaf tissue damage was 25% to 75%.

3. Stems firm, portions of leaf tissue still green, but more than 75% of leaf tissue killed.

4. Leaf tissue killed, but stem firm and succulent.

5. Base of stem soft and apparently having no life.

Ratings were taken at various times after treatment. At 24 hours after treatment, it was difficult to rate plants because the amount of leaf tissue damaged was questionable. At 48 hours after treatment, the amount of tissue damage was apparent and ratings were easy to obtain. At approximately 72 hours after treatment, the plants that were not severely damaged showed signs of growth. It appeared that the more vigorous plants recovered quicker and with a higher survival percentage than the less vigorous plants with the same damage ratings. All information was recorded 48 to 72 hours after treatment.

The one- to five-rating system proved to be inadequate after the heat chamber was remodeled. Through the remainder of the experiments the following system was used:

1. 00-20% of leaf area showing dehydration
2. 20-30% of leaf area showing dehydration
3. 30-40% of leaf area showing dehydration
4. 40-50% of leaf area showing dehydration
5. 50-60% of leaf area showing dehydration
6. 60-70% of leaf area showing dehydration
7. 70-80% of leaf area showing dehydration
8. 80-90% of leaf area showing dehydration
9. 90-100% dehydration of leaf area but stem firm and succulent
10. Complete dehydration of leaves. Stem shrivelled or blackened.

RESULTS AND DISCUSSION

Results of Open-Pollinated Variety Test

The eight open-pollinated varieties were the first seedlings to be tested in the heat chamber. It was desired to know if the heat chamber was functioning in such a manner that reliable results could be obtained. These varieties have been grown in Oklahoma for many years and opinions have been formed as to their ability to withstand drought.

The various varieties seemed to have definite trends in their tolerance to heat, but there was so much variation within varieties that it was difficult to obtain reliable results. Statistical analysis showed that the desired results could be obtained by additional replication. Significant differences were obtained by analyzing information from 12 replications.

The eight varieties had approximately the same relative heat chamber performance as they have been observed to have under droughty field conditions. As shown in Table I, the information seemed to be reliable, but a great amount of time and effort was required to obtain this information.

Results of Hybrid Test

The Hybrid Test was conducted to determine whether or not results comparable to the Open-pollinated findings could be obtained.

Seven commercial Hybrids, that have been entered in state yield tests during droughty years, and one open-pollinated variety from the previous test were used. Again the varietial damage ratings were in the approximate order as observed under droughty field conditions. There appeared to be less variation among Hybrids than Open-pollinated varieties. Twenty replications gave the desired results but this would require too much effort to be practical for routine work.

In Table II the average of all Hybrids tested in all replications was 4.22 as compared with 3.60 for the Open-pollinated varieties shown in Table I. The Open-pollinated check variety 184 had a damage rating of 4.49 when treated with the Hybrids, but only 3.78 when treated with the Open-pollinated varieties. No attempt was made to explain this variation.

Results of Inbred Test

The Inbred test was conducted to learn if results comparable to the previous experiments with hybrids and open-pollinated varieties could be obtained. The results of this experiment proved to be quite poor because the inbreds were damaged so severely that it was impossible to detect varietal differences. The amount of damage to plants at different locations within the heat chamber was so great that reliable results could not be obtained. As shown in table III, results were very erratic and therefore no more tests were conducted until after modification of the heat chamber as described in Material and Methods page 21.

TABLE I

COMPARATIVE HEAT DAMAGE RATINGS OF EIGHT OPEN-POLLINATED VARIETIES OF CORN TREATED AT 135°F. FOR EIGHT HOURS

Flat Number	Variety Number 1	2	3	4	5	6	7	8
				RUN I				
1	3.8	3.0	4.2	4.4	4.8	4.8	5.0	5.0
2	1.6	3.2	4.0	3.2	2.6	3.6	3.6	4.8
3	2.5	4.0	2.7	2.5	4.2	3.6	2.4	3.8
4	1.0	1.5	3.5	5.0	3.0	2.4	3.9	5.0
Total	8.9	11.7	14.4	15.1	14.6	14.4	14.9	18.6
				RUN II				
5	2.7	1.6	3.0	2.2	2.3	3.3	3.6	3.0
6	3.0	3.5	3.0	3.2	2.8	3.8	3.6	3.2
7	3.2	3.0	3.0	2.6	3.6	3.2	4.0	3.4
8	2.0	2.6	2.2	2.8	3.2	3.2	2.8	2.2
Total	10.9	10.7	11.2	10.8	11.9	13.5	14.0	11.8
				RUN III				
9	4.2	3.0	4.2	4.8	5.0	4.2	5.0	5.0
10	4.4	3.0	3.8	4.4	5.0	4.2	5.0	5.0
11	4.4	3.8	4.0	4.0	4.0	4.5	4.8	5.0
12	3.0	4.2	4.0	4.2	4.4	4.5	5.0	4.6
Total	16.0	14.0	16.0	17.4	18.4	17.4	19.8	19.6

1. Ratings: 1 Least Damage, 5 Most Damage
2. Each rating is the average of a 5-plant row
3. Each run is the group of 4 flats that were in the heat chamber at the same time

TABLE I (Continued)

Analysis of Variance

Source	DF	MS	F
Total	95		
Varieties	7	2.228	7.15**
Reps	11	4.345	13.94**
Error	77	.3116	

* Significant at the 5% level
** Significant at the 1% level

Oklahoma Varieties	Variety No.	Total	Mean
1. Yellow Surecropper	119	35.8	2.98
2. Oklahoma White Wonder	153	36.4	3.03
3. Woods Corn	113	41.6	3.47
4. White Pencil Cob	154	43.3	3.61
5. Pride of Kansas	140	44.9	3.74
6. Mass Selection	184	45.3	3.78
7. Mexican June	146	48.7	4.06
8. Roley White	172	50.0	4.16
L. S. D.		.452 @ 5%	
		.601 @ 1%	

TABLE II

COMPARATIVE HEAT DAMAGE RATINGS OF SEVEN HYBRIDS AND ONE OPEN-POLLINATED VARIETY OF CORN TREATED AT 135°F. FOR EIGHT HOURS

	Flat Number	Hybrid or Variety Number							
		1	2	3	4	5	6	7	8
	1	3.4	4.0	3.2	4.6	4.0	4.8	4.4	4.0
RUN	2	3.8	4.6	3.2	3.4	4.4	5.0	4.8	4.4
I	3	3.2	4.0	4.0	5.0	4.8	4.8	5.0	5.0
	4	2.4	3.8	4.8	4.2	4.6	5.0	4.6	3.6
Total		12.8	16.4	15.2	17.2	17.8	19.6	18.8	17.0
	5	2.2	3.0	1.4	3.0	3.8	3.2	4.8	5.0
RUN	6	3.5	2.7	1.2	2.6	4.8	4.2	1.8	4.4
II	7	2.8	2.8	4.0	3.4	4.0	4.4	4.2	5.0
	8	1.8	2.6	3.8	1.4	4.0	3.2	4.5	2.0
Total		10.3	11.1	10.4	10.4	16.6	15.0	15.3	16.4
	9	4.6	2.2	5.0	3.8	4.2	2.8	5.0	4.4
RUN	10	4.6	5.0	5.0	5.0	5.0	4.2	5.0	5.0
III	11	4.2	4.8	4.2	5.0	4.4	4.4	5.0	5.0
	12	3.6	2.4	5.0	4.6	4.0	5.0	4.4	4.0
Total		17.0	14.4	19.2	18.4	17.6	16.4	19.4	18.4
	13	4.2	4.5	4.0	5.0	3.2	4.8	4.2	4.4
RUN	14	5.0	4.0	4.2	4.2	4.0	5.0	4.0	4.8
IV	15	4.4	2.7	3.0	4.0	4.0	3.0	4.8	4.8
	16	4.6	4.8	5.0	4.5	5.0	5.0	5.0	5.0
Total		18.2	16.0	16.2	17.7	16.2	17.8	18.0	19.0
	17	5.0	5.0	5.0	4.4	5.0	5.0	4.4	5.0
RUN	18	4.4	4.5	4.0	5.0	5.0	5.0	3.8	5.0
V	19	4.8	5.0	5.0	5.0	5.0	5.0	5.0	5.0
	20	4.8	5.0	5.0	5.0	5.0	5.0	5.0	5.0
Total		19.0	19.5	19.0	19.4	20.0	20.0	18.2	20.0

1. Ratings: 1 Least Damage, 5 Most Damage

2. Each rating is the average of a 5-plant row

3. Each run is the group of 4 flats that were in the heat chamber at the same time

TABLE II (Continued)

Analysis of Variance

Source	DF	MS	F
Total	159		
Variety	7	1.594	3.395**
Reps	19	2.883	6.142**
Error	133	.4694	

* Significant at the 5% level
** Significant at the 1% level

Varieties	Variety No.	Total	Mean
1. Oklahoma	301	77.3	3.86
2. Texas	30	77.4	3.87
3. Kansas	2234	80.0	4.00
4. Oklahoma	1815 (ex)	83.1	4.15
5. U. S.	13	88.2	4.41
6. Kansas	1859	88.8	4.44
7. O. P. Variety (Okla)	184	89.7	4.49
8. North Carolina	1032	90.8	4.54
L. S. D.			.259 @ 5%
			.558 @ 1%

TABLE III

COMPARATIVE HEAT DAMAGE RATINGS OF TWENTY INBRED LINES OF CORN TREATED AT 135^{o} F. FOR EIGHT HOURS

Inbred No.	Rep. 1	Rep. 2	Rep. 3	Rep. 4	Total	Mean
1	3.20	3.50	3.71	4.25	14.66	3.66
2	4.28	3.50	4.87	3.63	16.28	4.07
3	4.66	3.63	4.63	3.43	16.35	4.08
4	4.66	2.50	5.00	4.25	16.41	4.10
5	4.80	2.00	4.86	4.87	16.53	4.13
6	4.50	3.12	4.25	4.75	16.62	4.15
7	4.66	3.14	4.00	5.00	16.80	4.20
8	4.50	4.50	4.75	3.37	17.12	4.28
9	3.50	3.71	5.00	5.00	17.21	4.28
10	3.80	3.83	4.87	4.75	17.25	4.31
11	4.83	4.75	5.00	3.00	17.58	4.39
12	5.00	4.25	5.00	3.37	17.62	4.41
13	5.00	3.71	4.62	4.50	17.83	4.46
14	5.00	3.50	4.87	4.50	17.87	4.47
15	5.00	4.00	4.87	4.70	18.57	4.64
16	4.80	4.17	5.00	4.83	18.80	4.70
17	4.75	4.43	5.00	4.80	18.98	4.75
18	5.00	4.00	5.00	5.00	19.00	4.75
19	4.75	4.60	5.00	5.00	19.35	4.84
20	4.82	5.00	5.00	4.87	19.69	4.72
Total	91.51	75.84	95.30	87.87	350.52	4.38
Mean	4.58	3.79	4.78	4.39		

Means of Lines Not Significantly Different.

TABLE III (Continued)

Analysis of Variance

SOURCE	DF	MS	F
Total	79		
Varieties	19	.41721	1.2945
Replications	3	3.55	11.0937**
Error	57	.320228	

* Significant at the 5% level
** Significant at the 1% level

KEY TO INBREDS

1. 119-2-2-1-3-1
2. OK 11
3. RYD 11-117-3-4
4. KY 106
5. 116-0-126-3-1-2-1-2
6. 116-0-126-3-1-2-2-4
7. 116-0-126-3-1-2-1-3
8. RYD 11-118-1-1
9. NC 88
10. K 159
11. CI 7
12. RYD 11-117-3-1
13. 116-0-126-3-1-2-2-3
14. OK 12
15. OK 15
16. 77 C
17. K 4
18. HY
19. 38-11
20. CI 21 E

Results of Age, Light, and Temperature Study

At this time the specific objective of the study had been changed to methods and techniques for evaluating plants rather than the actual evaluation of genetically variable material. The heat chamber had been remodeled so that very little temperature variation occurred and its operation had proved to be very dependable. Unpublished data by Metcalfe (28) indicated that age, light, and temperature did have a very definite effect on the hardening of plants. However, it was believed that additional information needed to be obtained before the heat chamber used in this study could become most effective.

It also became necessary to use a different rating system to properly evaluate the amount of damage to the plants. Throughout the remainder of this experiment the 1-10 system as shown on page 29 of Materials and Methods was used. Figures 1 through 6 illustrate the results obtained from this study.

Heyne and Laude (14) found that 20-day old plants were more susceptible to heat and concluded that this was because stored food reserves were completely exhausted in the 20-day old plants. They found that plants began to become more hardy at a slightly older age. As shown in table IV of this study there were no apparent differences between plants 15, 17, and 19 days of age. The 21- and 23-day old plants were progressively more hardy. This would indicate that the stored food supply of the plants was at a minimum at the three younger ages and that the plants photosynthetic ability became more adequate after 21 days of age.

Growth of plants used in this experiment occurred very rapidly. This very rapid growth probably consumed the stored nutrients from the endosperm more rapidly and thus accounts for the decline in hardiness at an age younger than in the experiment conducted by Heyne and Laude (14).

The amount of sunlight that plants received immediately before they were placed in the heat chamber proved to be highly significant. Great differences between treatments of light and dark conditions were noted at 130° F., 135° F., and at 140° F. Sunlight was very intense prior to treatment time in each of the above mentioned treatments. When plants were treated at 120° F. the "dark" run was not started until 10:00 A.M. due to a malfunction of the heat chamber at 6:00 A.M. It was assumed that this comparison would not produce valid results for the comparison of light conditions. However, the experiment was continued because a delay would change the age of plants at treatment time throughout the remainder of the experiment. In table IV it is quite interesting to compare the light and dark treatments at 125° F. Since the sun was completely obscured until after the time of treatment, it was assumed that photosynthesis was taking place at a very slow rate and thus the plants had stored only limited amounts of food at the time of treatment.

Different temperatures produced the expected results of progressively more damage except the 125° F. treatment which received more damage than either the 130° F. or the 135° F. treatments. It is believed that this variation could be the result of the obscured sky condition prior to the time of treatment at 125° F. It is also believed that the overcast sky condition prior to the time of treatment at 120° F. influenced these results. If only the information obtained when plants were placed in the heat chamber before daylight was considered, progressive increases in damage were obtained with each increase in temperature.

A slight variation in position effect within the heat chamber did occur with position one producing slightly more damage than position two and position two producing slightly more damage than position three or four. It was believed that this variation was not too serious because the difference was slight compared to other variables. If four replications, each consisting of a different flat were used, position differences could be handled statistically.

TABLE IV

HEAT CHAMBER STUDIES TO DETERMINE THE EFFECT OF AGE, LIGHT, AND TEMPERATURE ON CORN SEEDLINGS

		Dark						Light				
120° F.		10:A.M. to 4:P.M.						6:P.M. to 12:P.M.				
	Rep	15	17	19	21	23	Rep	15	17	19	21	23
	1	2.1	3.1	5.1	2.6	2.5	1	1.4	1.1	1.9	1.8	1.8
Sky condition -	2	1.8	1.5	2.8	1.5	1.3	2	1.6	1.5	1.5	1.5	1.3
overcast	3	1.3	1.3	1.3	1.1	1.1	3	1.6	1.4	1.5	1.5	2.0
Soil Temp. 95° F.	4	1.0	2.0	1.6	1.8	1.1	4	1.3	1.4	2.0	1.3	1.9
	Total	6.2	7.9	10.8	7.0	6.0		5.9	5.4	6.9	6.1	7.0
125° F.		6:A.M. to 12:A.M.						12:30P.M. to 6:30P.M.				
	1	4.4	5.8	4.4	3.3	2.5	1	6.8	7.0	6.4	5.1	5.4
Sky condition -	2	4.1	4.8	3.4	3.3	3.3	2	5.5	7.1	6.4	5.4	4.3
obscured	3	3.4	3.5	3.6	3.3	3.3	3	8.3	5.1	7.3	4.6	3.6
Soil Temp. 99° F.	4	4.4	4.4	3.9	3.9	3.4	4	6.3	6.4	6.4	4.6	4.6
	Total	16.3	18.5	15.3	13.8	12.5		26.9	25.6	26.5	19.7	17.9
130° F.		6:A.M. to 12:A.M.						12:30P.M. to 6:30P.M.				
	1	5.5	6.1	6.7	5.3	5.8	1	1.8	3.4	1.3	2.3	1.0
Sky condition -	2	5.8	6.3	6.0	5.0	4.9	2	1.1	1.1	1.0	1.3	1.3
clear, bright	3	5.1	5.4	4.7	4.7	4.4	3	1.1	1.4	1.0	1.4	1.0
Soil Temp. 102° F.	4	5.8	6.4	5.8	5.1	4.6	4	1.3	1.1	1.5	1.1	1.3
	Total	22.2	24.2	23.2	20.1	19.7		5.3	7.0	4.8	6.1	4.6
135° F.		6:A.M. to 12:A.M.						12:30P.M. to 6:30P.M.				
	1	6.4	5.3	5.6	5.3	4.3	1	3.5	3.1	3.4	3.5	3.3
Sky condition -	2	6.1	5.9	5.1	4.8	4.8	2	4.4	4.8	3.6	3.1	4.1
clear, bright	3	6.3	5.6	5.6	4.5	4.5	3	4.6	4.5	3.4	3.0	3.1
Soil Temp. 106° F.	4	5.9	5.4	5.8	5.8	5.1	4	4.8	5.5	4.9	4.4	3.0
	Total	24.7	22.2	22.1	20.4	18.7		17.3	17.9	15.3	14.0	13.5
140° F.		6:A.M. to 12:A.M.						12:30P.M. to 6:30P.M.				
	1	9.3	8.9	8.9	7.5	8.0	1	7.9	6.9	7.8	3.4	6.1
Sky condition -	2	8.5	9.3	7.3	7.9	7.0	2	8.1	6.4	7.0	6.9	5.8
clear, bright	3	8.3	7.9	8.0	6.4	6.6	3	6.4	6.9	7.9	5.4	6.1
Soil Temp. 111° F.	4	8.0	7.6	8.3	7.0	6.1	4	5.6	4.3	4.8	5.1	3.3
	Total	34.1	33.7	32.5	28.8	27.7		28.0	24.5	27.5	20.8	21.3
Combined Total		103.5	106.5	103.9	90.1	84.6		83.4	80.4	81.0	66.7	64.3

TABLE IV (Continued)

Ratings Taken 48 Hours After Treatment

Temp.	Totals	Age	Totals	Position	Totals	Light	Totals
120°	69.2	15	186.9	1	232.1	Dark	488.6
125°	193.0	17	186.9	2	218.6	Light	375.8
130°	137.2	19	184.9	3	205.3		
135°	186.1	21	156.8	4	208.4		
140°	278.9	23	148.9				
Total	864.4		864.4		864.4		864.4

Analysis of Variance

Source	DF	SS	MS	F
Total	199	999.94		
Light	1	63.61	63.61	163.1 **
Temp.	4	596.06	149.01	382.1 **
Age	4	34.08	8.52	21.8 **
Rep (Position)	3	8.76	2.92	7.49**
Interaction				
L X T	4	197.09	49.27	126.33**
L X A	4	0.81	0.20	0.51
T X A	16	17.46	1.09	2.79**
L X R	3	4.48	1.49	3.82**
T X R	12	18.33	1.53	3.92**
A X R	12	3.96	0.33	0.84
L X T X A	16	8.34	0.52	1.33
Error	120	46.96	0.39	

* Significant at the 5% level

** Significant at the 1% level

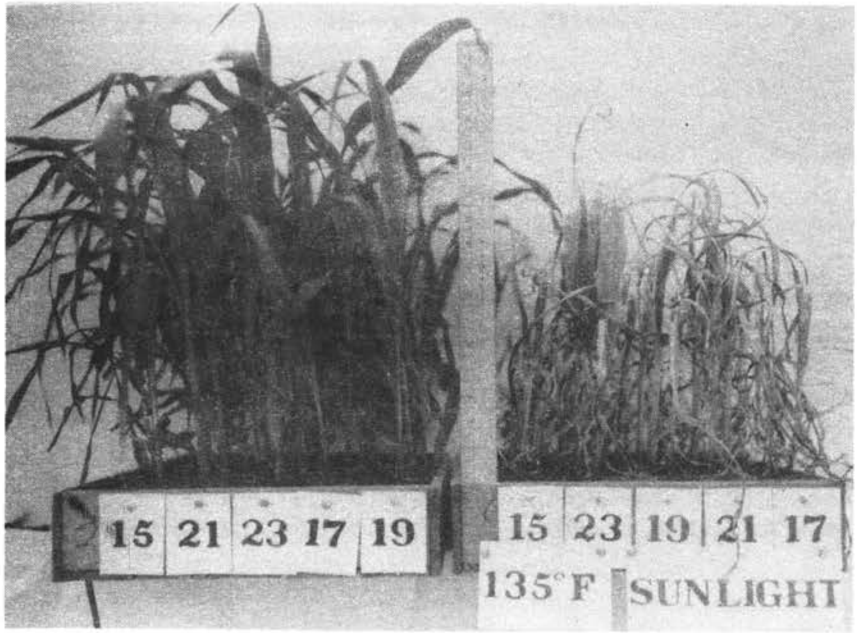

Figure 1. Green house flat on left shows condition of plants prior to treatment. Flat on right shows plants 48 hours after being subjected to temperature of 135^{o} F. for 6 hours.

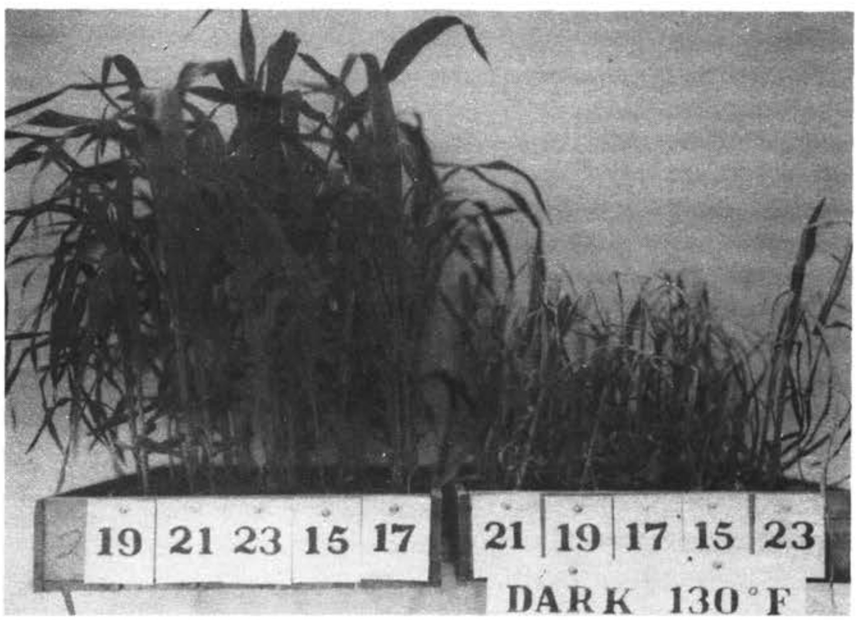

Figure 2. Flat on left shows conditions of plants prior to treatment. Flat on right shows plants that received no sunlight prior to time of treatment.

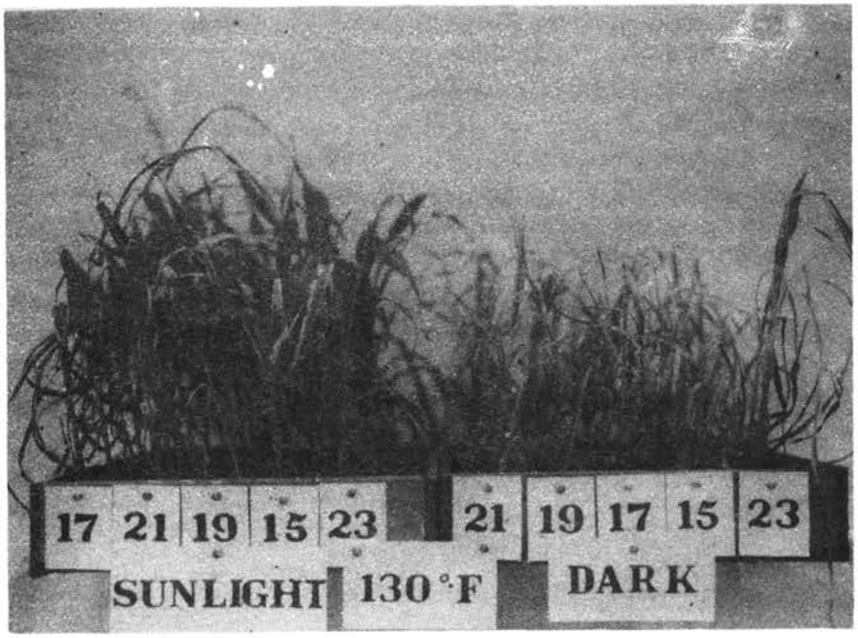

Figure 3. A comparison of plants that received no sunlight prior to treatment and plants that received approximately 6 hours sunlight prior to treatment.

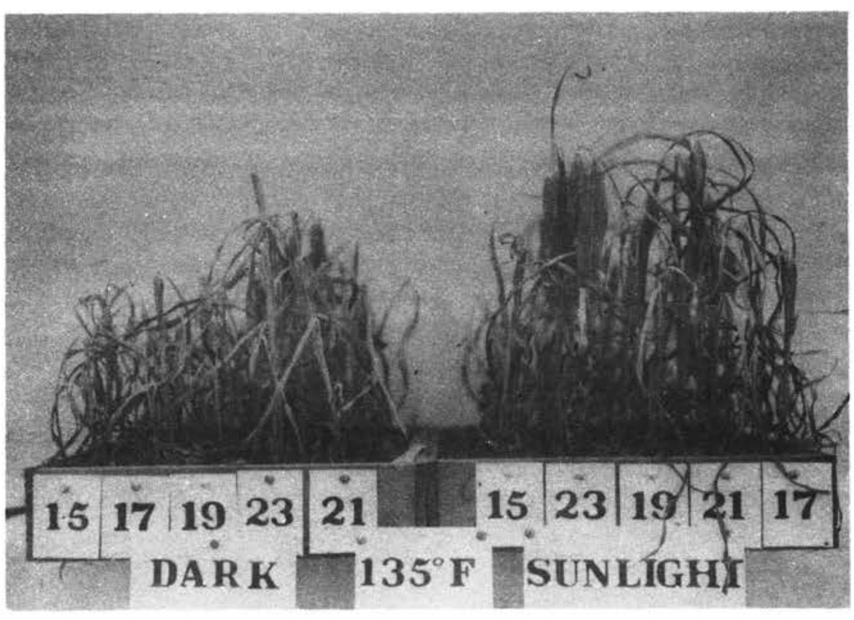

Figure 4. A comparison of plants receiving no sunlight prior to treatment of 135 ^{o} F. and plants receiving approximately 6 hours sunlight prior to treatment.

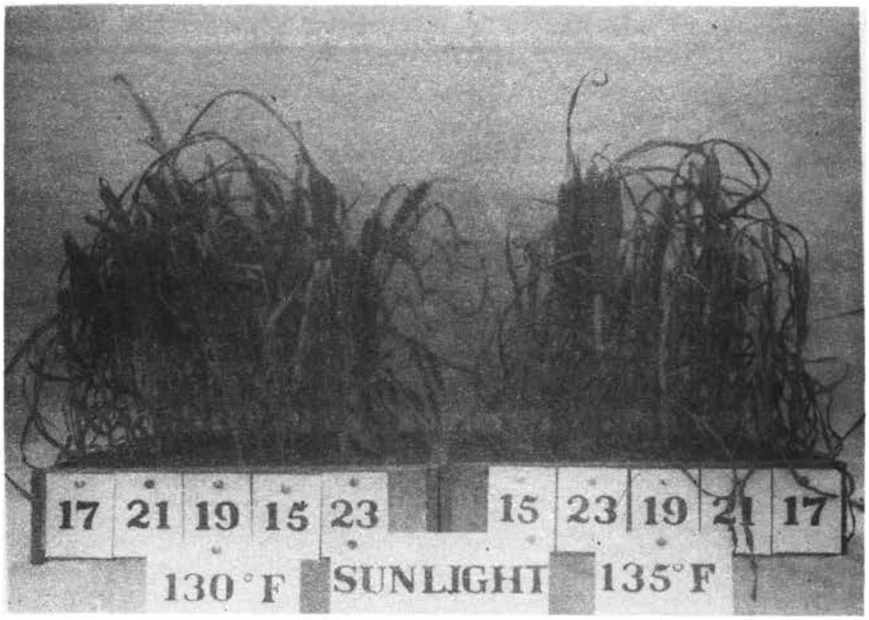

Figure 5. A comparison of plants that received approximately 6 hours sunlight and then treated at temperatures of 130° F. and 135° F.

Figure 6. A comparison of plants that received no sunlight prior to treatment with temperatures of 135° F. and 140° F.

Survival of Plants after Treatment with High Temperatures at Different Ages and Different Light Conditions

In addition to using the heat chamber for evaluating different strains of corn, it was thought desirable to also use it as a device to eliminate susceptible plants from genetically variable material. Before this could be accomplished, some information about the survival ability of corn plants needed to be obtained. The plants used in the Age, Light, and Temperature Study were also used in the Survival Study.

The Variety OK 301 was used in this study because it was believed to possess moderate heat tolerance. It was believed that if plants could be subjected to conditions that would kill 40 to 60% of the heat-tolerant plants, then most of the less tolerant plants should be eliminated.

As shown in table V and figures 7 through 10, plants exposed to light prior to treatment had excellent survival ratings, even at higher temperatures. Plants that received no sunlight prior to treatment were damaged much more severely and thus had only fair survival. Age of plants at the time of treatment had a definite influence on survival of plants with a progressive increase in survival percent from 15 to 23 days of age.

Results from this brief study indicate that plants between the ages of 15 and 21 days could be taken from darkness and treated with temperatures of 130^{o} to 135^{o} to obtain survival of 40 to 60% of the plants. Surviving plants that started growing within five days after treatment grew rapidly to a plant height of more than 36 inches. None of the plants were kept after they reached this size, but they appeared to be very vigorous and capable of reproduction.

TABLE V

SURVIVAL PER CENT OF CORN PLANTS TREATED WITH HIGH TEMPERATURE AT DIFFERENT AGES AND LIGHT CONDITIONS

Ratings taken 5 - 7 days after treatment.

	Dark					Light				
Age	15	17	19	21	23	15	17	19	21	23
130° F.										
	62	62	43	75	50	100	100	100	100	100
	50	50	25	25	62	100	100	100	100	100
	50	50	62	37	62	100	100	100	100	100
	62	12	37	50	75	100	100	100	100	100
Mean	56.0	43.5	41.8	46.8	62.3	100	100	100	100	100
135° F.										
	15	50	50	88	100	100	100	88	88	100
	25	50	50	88	88	88	88	100	100	88
	12	50	62	88	100	75	88	75	100	86
	25	12	37	100	100	88	63	75	100	100
Mean	19.2	40.5	50.0	91.0	97.0	87.8	84.8	84.5	97.0	93.5
140° F.										
	12	12	0	37	0	12	37	12	100	75
	0	0	0	25	50	37	50	12	25	62
	12	0	0	50	50	50	62	25	100	50
	0	12	0	12	75	62	100	87	75	100
Mean	6.0	6.0	0.0	31.0	43.8	40.3	62.5	34.0	75.0	71.8

Figure 7. This illustration shows the condition of plants 7 days after treatment with temperatures of 135° F. and 140° F.

Figure 8. Illustration of the recovery ability of plants treated with temperatures of 130° F. and 135° F.

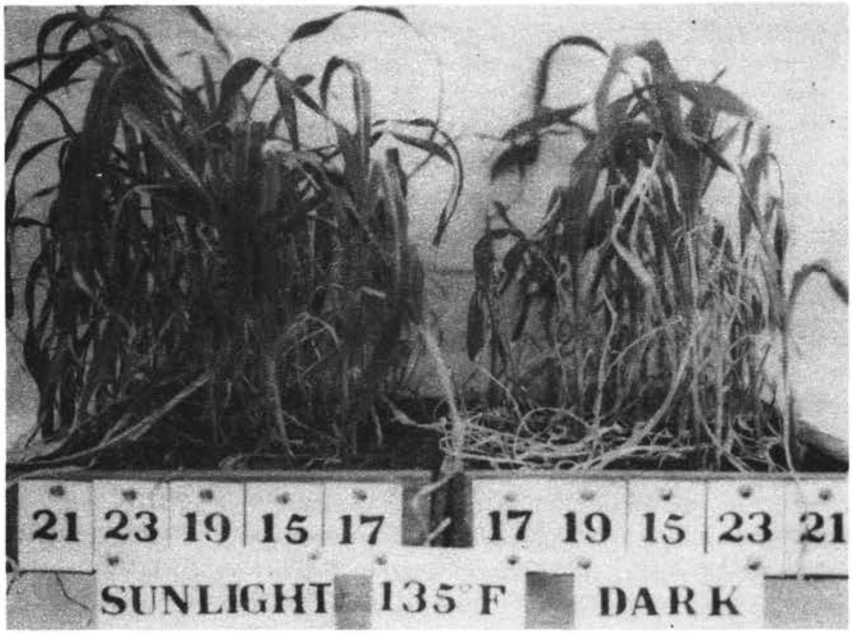

Figure 9. A comparison of the recovery ability of plants receiving no sunlight and plants receiving 6 hours sunlight prior to treatment at 135° F.

Figure 10. A comparison of the recovery ability of plants receiving no sunlight and plants receiving 6 hours sunlight prior to treatment at 140° F.

Results of the Age, Variety, and Temperature Study

This experiment was conducted to supplement information obtained in the Age, Light, and Temperature Study and to determine if variety interactions would be a significant factor. Since each flat contained two different ages of open-pollinated plants, two ages of hybrid plants, two ages of a single cross line and two ages of an inbred line, a considerable amount of information could be obtained from the 20 flats of plants used in this study.

Results listed in table VI show that the older plants were significantly more hardy than the younger ones as they were in the Age, Light, and Temperature Study. Hardiness increased progressively from 19 to 25 days of age, however, the comparison of 23-day plants to 25-day plants indicated that a "leveling off" effect was taking place.

When each of the five runs was statistically analyzed as a simple experiment containing four replications, age proved to be a significant factor in three of the five runs, two of which were significant at the 1% level.

Considerable variation among the four varieties was apparent with the hybrid having the least amount of damage in nine of the ten comparisons. The open-pollinated variety ranked first in one of the tests, second in five tests and third in the remaining four tests. The single cross strain was second in five tests, third in three tests and received the greatest amount of damage in two of the tests. The inbred variety was third in only two of the comparisons and received the greatest amount of damage in the remaining eight comparisons. The four varieties had the following damage ratings when totals from the ten comparisons were combined: Hybrid 172.3, Open-pollinated 197.7, Single Cross 204.9, and Inbred 232.6. These ratings were significant at the 1% level when analyzed as a factorial in a randomized block.

The design of this experiment permitted varietal variation to be analyzed statistically several different ways. When the analysis of variance for varieties was computed using 40 replications and 20 replications, results proved to be highly significant. When each run of four flats was statistically analyzed and each flat considered to be a replication, significance at the 1% level occurred in two of the five runs, significance at the 5% level in one run, and significance at the 10% level in the remaining two runs. Since run one and four showed the least amount of varietal difference, the data from these two runs were combined and when statistically analyzed proved to be significant. It, therefore, was assumed that it would take between four and eight flats, each containing four varieties, to obtain significant information with these varieties.

Variation in temperature produced results similar to those obtained in the Age, Variety, and Temperature Study. Damage was progressively greater at the higher temperatures except when influenced by a light condition. When temperature variation was analyzed statistically, it proved to be highly significant. However, this variation in temperature produced very little if any interaction with age or variety. It was, therefore, believed that most any temperature was satisfactory if it produced the proper amount of damage to plants.

TABLE VI

THE EFFECTS OF AGE, VARIETY, AND TEMPERATURE ON CORN SEEDLINGS

135° F.
Light

		23 days of age						25 days of age				
		OP	HY	SC	IN			OP	HY	SC	IN	
Sky Condition	1	4.4	4.0	4.0	3.4	15.8	1	3.0	4.0	4.0	5.2	16.2
	2	2.4	1.0	2.0	3.2	8.6	2	3.6	1.4	1.2	2.3	8.5
Broken	3	2.0	1.4	4.2	2.8	10.4	3	2.5	2.0	3.6	2.6	10.7
	4	1.8	3.2	3.4	3.2	11.6	4	2.2	1.6	4.0	2.5	10.3
		10.6	9.6	13.6	12.6	46.4		11.3	9.0	12.8	12.6	45.7

135° F.
Dark

		21 days of age						23 days of age				
Sky Condition	1	5.8	5.8	7.0	9.5	28.1	1	5.5	3.8	6.4	7.4	23.1
	2	10.0	5.2	7.4	8.0	30.6	2	7.6	5.0	8.0	9.6	30.2
Broken	3	6.4	7.8	6.8	9.8	30.8	3	6.0	5.8	7.0	9.0	27.8
	4	6.3	6.0	8.4	9.6	30.3	4	4.4	4.6	5.6	6.5	21.1
		28.5	24.8	29.6	36.9	119.8		23.5	19.2	27.0	32.5	102.2

135° F.
Light

		19 days of age						21 days of age				
Sky Condition	1	6.2	6.6	6.4	8.2	27.4	1	6.6	6.0	5.2	6.0	23.8
	2	5.6	5.6	8.0	8.0	27.2	2	5.4	6.3	6.2	7.2	25.1
Overcast	3	10.0	9.0	7.4	10.0	36.4	3	7.2	6.4	7.3	9.3	30.2
	4	5.0	6.2	6.0	7.7	24.9	4	7.4	5.0	6.6	5.8	24.8
		26.8	27.4	27.8	33.9	115.9		26.6	23.7	25.5	28.3	103.9

140° F.
Light

		21 days of age						23 days of age				
Sky Condition	1	5.2	3.2	5.8	5.0	19.2	1	4.8	3.6	3.6	3.4	15.4
	2	4.8	4.8	5.6	4.8	20.0	2	6.6	3.8	4.4	6.7	21.5
Scattered	3	4.4	4.2	4.8	7.8	27.9	3	3.4	4.0	5.2	4.2	16.8
	4	8.8	6.6	6.0	6.5	27.9	4	4.0	4.4	5.6	7.5	21.5
		23.2	18.8	22.2	24.1	88.3		18.8	15.8	18.8	21.8	75.2

TABLE VI (Continued)

130^{o} F.

Light

		21 days of age						23 days of age				
Sky Condition	1	3.8	3.4	3.2	4.4	14.8	1	3.6	2.4	3.2	3.8	13.0
	2	3.4	2.4	3.2	3.4	12.4	2	3.4	2.4	3.6	3.5	12.9
Scattered	3	3.4	3.4	3.6	4.0	14.4	3	3.2	3.0	3.2	3.4	12.8
	4	4.0	3.2	4.2	3.8	15.2	4	3.6	3.8	3.6	3.6	14.6
		14.6	12.4	14.2	15.6	56.8		13.8	11.6	13.6	14.3	53.3
		103.7	93.0	107.4	123.1	427.2		94.0	79.3	97.5	109.5	380.3

Analysis of Variance

SOURCE	DF	SS	MS	F
Total	159	699.12		
Runs	4	453.79	113.45	94.54**
Reps (position)	3	3.56	1.19	0.99
Age	1	13.75	13.75	11.46**
Variety	3	46.13	15.38	12.82**
A X V	3	0.37	0.12	0.10
Run X V	12	20.62	1.72	1.43
Run X A	4	6.20	1.55	1.29
Error	129	154.70	1.20	

* Significant at the 5% level

** Significant at the 1% level

TABLE VI (Continued)

Variety Analysis of Variance for 40 Replications

SOURCE	DF	SS	MS	F
Total	159	699.12		
Reps	39	549.92	14.10	16.02**
Variety	3	46.13	15.38	17.48**
Error	117	103.07	0.88	

Variety Analysis of Variance for 20 Replications

SOURCE	DF	SS	MS	F
Total	79	1239.07		
Reps	19	1034.84	54.47	27.79**
Variety	3	92.27	30.76	15.70**
Error	57	111.96	1.96	

TABLE VII

Variety Analysis of Variance for Individual Runs

Run 1

Total	31	34.87		
Reps	3	15.07	5.02	9.65**
Variety	3	4.61	1.54	2.96
Age	1	0.01	0.01	0.00
R X V	9	8.78	0.98	1.88
V X A	3	0.18	0.06	0.12
Error	12	6.22	0.52	

* Significant at the 5% level

** Significant at the 1% level

TABLE VII (Continued)

Variety Analysis of Variance for Individual Runs

		Run 2		
Total	31	87.79		
Reps	3	9.12	3.04	2.74
Variety	3	42.36	14.12	12.72**
Age	1	9.68	9.68	8.72**
Error	24	26.63	1.11	
		Run 3		
Total	31	56.93		
Reps	3	23.05	7.68	9.14**
Variety	3	9.15	3.05	3.63**
Age	1	4.50	4.50	5.36**
Error	24	20.23	0.84	
		Run 4		
Total	31	59.13		
Reps	3	15.09	5.03	3.96**
Variety	3	8.24	2.75	2.17
Age	1	5.38	5.38	4.24*
Error	24	30.42	1.27	
		Run 5		
Total	31	6.60		
Reps	3	1.29	0.43	3.91*
Variety	3	2.37	0.79	7.18**
Age	1	0.39	0.39	3.55
Error	24	2.55	0.11	

* Significant at the 5% level
** Significant at the 1% level

TABLE VIII

Variety Analysis of Variance for Two Runs Combined

SOURCE	DF	SS	MS	F
		Run 1 and 2		
Total	63	386.33		
Reps	3	3.19	1.06	0.73
Variety	3	34.59	11.53	7.95**
Age	1	5.24	5.24	3.61
Run	1	263.66	263.66	181.83**
Error	55	79.65	1.45	
		Run 1 and 4		
Total	63	173.66		
Reps	3	7.07	2.36	1.79
Variety	3	11.16	3.72	2.82*
Age	1	2.95	2.95	2.23
Run	1	79.65	79.65	60.34**
Error	55	72.83	1.32	
		Run 2 and 3		
Total	63	144.80		
Reps	3	23.55	7.85	6.83**
Variety	3	44.31	14.77	12.84**
Age	1	13.69	13.69	11.90**
Run	1	0.08	0.08	
Error	55	63.17	1.15	

* Significant at the 5% level

** Significant at the 1% level

SUMMARY AND CONCLUSIONS

At the beginning of this study an attempt was made to evaluate the heat tolerance of several different strains of corn by the use of a heat chamber. The air was forced over the plants at a rather strong velocity to produce a wind tunnel effect. Variation of temperature and air velocity at different locations within the heat chamber made it difficult to obtain the desired information. The design of the heating system was changed and air was forced through the chamber from above to obtain a uniform temperature at each horizontal level within the chamber.

After the first method of testing proved that more basic information was needed, the purpose of this experiment was changed to devising the technique for growing plants and treating them with high temperature in such a way genetic variation of heat tolerance could be determined. The review of literature indicates that many environmental factors influence the tolerance of plants to high temperatures. Some of the variables are as follows: age of plant, growing condition of plant, hardening of plants at different temperatures, hardening of plants under moisture stress, the amount of sunlight received by the plant prior to treatment, the amount of carbon dioxide received by the plant, and other enviornmental factors.

For this study research was conducted to determine the effects of the treatment of corn plants at different ages, different temperatures, and the effects of pre-exposing the plants to different amounts of sunlight. Studies were also conducted to determine interaction of the above mentioned factors with different varieties. An attempt was made to treat plants in such a manner that less hardy plants could be destroyed, thus using the heat chamber as a selection tool.

The conclusions reached from these studies may be summarized as follows:

(1) By the use of the heat chamber as originally constructed, differences between varieties could be determined but so much variation occurred within the chamber that 12 replications were required when eight open-pollinated varieties were used and 20 replications when seven hybrids and one open-pollinated check variety were used. More basic information was needed.

(2) The hybrids and open-pollinated varieties had approximately the same relative performance in the heat chamber as they have been observed to have under droughty field conditiions.

(3) The age of plants has a very definite effect on the way they will withstand high temperatures. Plants of 15, 17, and 19 days of age had about the same amount of resistance to high temperatures. Plants of 21 and 23 days of age were progressively more hardy than younger plants.

(4) Corn plants of 15 days of age or older can be subjected to temperatures of 120° to 140° F. for a duration of six hours and the amount of heat damage determined at all temperatures. Only slight damage readings were obtained at 120° F. while severe damage occurred at 140° F. However, several of the plants were capable of survival at the higher temperatures.

(5) The amount of sunlight received by the plants prior to treatment greatly affected the ability of plants to withstand high temperatures.

(6) When plants received sunlight prior to treatment, all plants survived at 130° F. while only 50% of the plants survived when treated

at 130° F. before any sunlight was received. After subjecting plants to 140° F., 17% of the plants that did not receive sunlight prior to treatment survived and 57% of the plants survived after receiving six hours of sunlight.

(7) When four different varieties consisting of a hybrid, open-pollinated variety, a single cross, and an inbred line were subjected to high temperatures, highly significant differences occurred. The hybrid received the least amount of damage, the inbred the greatest amount of damage, and the open-pollinated and single cross strains intermediate amounts of damage.

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VITA

James Wendell Echols

Candidate for the Degree of

Master of Science

Thesis: A METHOD FOR DETERMINING DROUGHT TOLERANCE IN CORN BY THE APPLICATION OF HIGH TEMPERATURE

Major Field: Field Crops

Biographical:

Personal data: Born in Blair, Oklahoma, November 2, 1931, the son of James S. and Cleo B. Echols.

Education: Attended grade school at Warren, Cordell, and Tipton, Oklahoma. Graduated from Tipton High School in May of 1949 and received the Bachelor of Science degree from Oklahoma State University, with a major in Agronomy, May, 1953. Completed the requirements for the Master of Science degree in Agronomy, August, 1964.

Professional experience: Served as a Platoon Leader, Company Executive Officer, and Batallion Motor Officer with the United States Army in Germany from October of 1953 to January of 1956. Received a graduate assistantship in the Agronomy Department, Oklahoma State University, January 1956 and performed that service until May of 1958. June 12, 1958 was appointed Secretary-Manager, Oklahoma Foundation Seed Stocks, Inc. and presently employed at that position.