DROUGHT AND HEAT RESPONSES IN SELECTED HYBRID AND INBRED LINES OF CORN

by

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INTRODUCTION

One of the most widely cultivated crops in the world is corn, Zea Mays L. Corn has become one of the staple foods for people throughout the world.

Drought is a limiting factor in the production of crops in semi-arid regions. An important goal of plant breeders is the development of lines or hybrids that will withstand adverse weather conditions and produce a crop under limited moisture conditions. Corn is grown extensively in areas where drought conditions frequently occur. It is a sub-tropical plant, and generally grows during the warmest season of the year when moisture shortage and dry, hot weather may prevail.

The success of the corn plant depends on the development of its vegetative parts. Proper root development is important; corn possesses roots extending five to six feet in depth, and has a relatively low water requirement. In the development of the roots, the root system is initiated during seedling establishment. The root functions as an anchorage for the plant as well as a part of the translocation system which taps the natural resources of the soil from the time the seed germinates until the plant completes its life cycle.

The flowering habit of corn is not well adapted to dry, hot regions. Low soil moisture delays silking. Under extreme conditions corn tassels often become desiccated in the hot dry winds.

Corn will probably continue to be grown in areas subject to drought in the semi-arid conditions, particularly in developing countries where corn is the basic part of the human diet of the poor working classes. As such conditions do prevail, research is necessary to measure differences in drought response of genetically different lines of corn, and to study root systems in relation to drought resistance. The task of the plant breeder is to produce lines that will be better suited to the environment.

The objectives of this study were to measure differences in drought response of genetically different hybrids of corn, and to study the effect of root systems upon the ability of these hybrids to withstand drought stress. It was postulated that the plants with the greater root volume would be in the most favorable position to resist drought. This character might enable the plant to utilize more efficiently the moisture present in a given volume of soil than would otherwise be possible. Also studied were some leaf traits and their responses to drought stress.

REVIEW OF LITERATURE

Severe droughts in the midwestern United States have stimulated interest in the development of genetic resistance to drought. During the period of 1933 to 1936, the region from the Dakotas to Texas and from Nevada to the Atlantic Ocean was scourged with drought.

Crops yields are a direct reflection of weather conditions. Yields may be roughly predicted from the weather over a period of time. In a semi-arid region the climatic conditions vary from year to year. Favorable and unfavorable climatic conditions can be expected. Thompson (1964) has called attention to the fact that the drought seasons appear to run in cycles.

The midwest has often been termed the "bread basket of the world." This area is subject to weather conditions unfavorable for plant growth. The unfavorable condition of drought involves a number of complex factors such as temperature and water. Drought is usually a condition of the soil or atmosphere that prevents the plant from obtaining sufficient water for metabolic functions. Drought resistance is the ability of the plant to tolerate both high temperature and low available water.

The general objective of drought research is to provide information or materials which will make dry-land farming a reasonably profitable enterprise. The use of drought resistant crops in the semi-arid region is an example of the application of drought research results. The chief limiting factor in the production in these regions is the lack of sufficient moisture. A number of means may be used to meet this deficiency. The use of irrigation can be used to supply water to the crops in some areas. In other areas lacking in a supply of useable water, tillage methods can be used to conserve water. The loss of water may be prevented by reducing the evaporation of soil moisture. Another means of solving the problem is to grow the most drought-resistant varieties that can be obtained. One of the principal factors that enters into drought resistance is the ability of a root system to utilize to the utmost a scanty supply of soil moisture. Also involved is the ability of the plant to reduce transpiration or loss of water through the leaves and stems when the air is dry.

The above ground plant parts have been studied in detail to determine the effects of the environment. Root systems have been investigated to a lesser extent. Slower progress of root studies has been due to many and varied edaphic factors which are difficult to control. Before the nineteenth century investigators were concerned with descriptive information of root systems. By the middle of the century researchers began to make a more detailed probe of of plant roots. Among the early workers were Schubert in 1855 as reported by Pavlychenko (1937) at the Minnesota Agricultural Experiment Station in 1889. Schubert used a trench-washing method to study corn roots. The procedure allowed him to determine the depth of penetration and to procure in bulk root materials of crops. Kny (1894), an English physiologist, correlated the growth of roots and shoots of corn. He determined that the roots and shoots functioned independently of each other. In 1900 and 1904, Ten Eyck (1904) made a quantitative study of root systems of many plants at the Kansas Agriculture Experiment Station. He noted that corn roots grew deeper and fed through a greater volume of soil than sorghum. Hays (1889) also studied the habits of root growth. Miller (1916) found that the maximum depth of root penetration for kafir and corn was six feet. Kafir possessed approximately twice as many secondary units (root hairs) as did corn, indicating that the primary and secondary roots of kafir were more fibrous than the corn plant.

Moisture, temperature, and light are environmental factors that may limit growth and development of plants. The availability of water is the principle factor which limits crop production in many areas of the world. Most of the water taken up by plants is through the root system. Livingston (1906) reported that seeds of Fouqueeris and Cerevs would fail to germinate in soil containing less than fifteen per cent moisture by volume. As the seed germinates a rapid elongation of the primary root sends the tip far into the soil. At the same time the aerial parts grow slowly. By the process of rapid root elongation and slow growth of the arerial parts, the plant is able to attain depths where moisture is present for adequate growth. According to Kearney and Shantz (1911), some plants can adapt drought evasive mechanisms by decreasing the leaf area, producing an extensive root system, and shortening the growing season. "Drought" is frequently taken to mean "dry weather," but from an agronomic view drought is a deficiency of soil moisture or accompanied by atmospheric conditions which induce high rates of evaporation. Shantz (1927) reported that plants cannot continue in an active growing condition when the soil moisture falls to half of the field carrying capacity. The wilting point is due to the nature of the physical forces of the soil which holds soil moisture and prevents movement of moisture.

Cook (1943) studied the root development of smooth bromegrass, *Bromus inermis*. He concluded that the total axial root length was one of best single measurements for evaluating root systems, but that the evaluation was incomplete unless a knowledge of depth, density, lateral spread and the amount of branching was considered.

Foth *et al*. (1960) described the pattern of root development. They observed that the corn roots developed laterally and vertically. The 35th day early root development showed a lateral growth in the upper foot of soil. It was noted that root development in a given volume of soil was completed before rapid root growth occurred in the soil more distant from the plant. He observed that only two per cent of the weight of roots occurred below a depth of two feet at maturity. Haber (1938) found no significant differences between weights of roots of susceptible and resistant inbred lines of corn that would account for differences in their ability to withstand drought.

Misra (1954) studied the root systems of four lines of corn K2234, K1830, K1784, and K1639. He observed that the drought resistant lines had a greater number of roots, more branching, and were better developed. Hague (1955) found that drought resistant strains of corn had root systems superior to other strains of corn because of their ability to continue drawing water in an increasing water deficit. He observed that the resistant strain had a higher root-top ratio, and more branching of secondary roots. Fayemi (1957) made an evaluation of techniques for studying root development of corn. He suggested that a soil zoning method, the use of radio-active isotopes, and a glass chamber method would be useful for screening corn seedling for root development of soil low in moisture.

Concentration of salts may vary from region to region in the soil. As the developing root system meets these different areas, the roots may have the ability to withstand these variations of salinity. Eaton (1941) noted that there is a direct relationship between soil moisture and its osmotic pressure.

MATERIALS AND METHODS

This investigation was divided into four parts including two field studies and two greenhouse studies. The information pertaining to the Materials and Methods and Results and Conclusions is presented in separate sections and in chronological order as follows: (a) Experiment I, 1963 field study; (b) Experiment II, Fall 1964 greenhouse study; (c) Experiment III, Spring 1965 greenhouse study, (d) Experiment IV, 1965 field study. Plant materials included in all four experiments consisted of ten single cross corn hybrids which were as follows: H28 x K41, H28 x K55, K11 x K708, K41 x K742, K55 x K699, K55 x K741, K63 x K740, K724 x K731, K731 x K776, and K755 x K786; and the inbred parents lines H28, K11, K41, K55, K63, K699, K708, K724, K731, K740, K741, K742, K755, K776, and K786.

Experiment I

The first experiment was planted in the summer of 1963. The plots were single rows twenty feet long with seeds planted about twelve inches apart in forty-inch rows. A randomized complete block design with four replications was used. Notes were taken during the summer on top firing and leaf rolling. The rating scale used was 0, no top firing or leaf rolling to 5, severe top firing or leaf rolling. Top firing referred to the amount of leaf tissue killed as a result of heat and drought. In the fall grain yields were taken.

Experiment II

The second part of the study took place in the agronomy greenhouse in the fall of 1964. The plants were grown in one gallon non-porous ceramic containers filled with a mixture of one-third soil, one-third sand, and one-third vermiculite. Drainage was provided at the bottom of each container. Plantings were made November 7, 1964. Two seeds were planted one inch deep in each container, and later thinned to one plant per container. The containers were placed in randomized complete blocks of four replications. Suitable soil moisture, temperature, and light conditions were maintained for good plant growth. The plants were uniformly fertilized with a 16-16-16 mixture of fertilizer. Red spider and aphids were controlled with insecticides. Measurements of the longest leaves of each plant were made to provide an estimation of leaf blade area. Number of leaves, tassel height, number of ears per plant were also noted. The roots were taken up and washed in February, 1965. The roots were immersed in water in a 1000 ml. graduated cylinder to measure root volume. The length of the root mass was also measured.

Experiment III

The third test, also conducted in the agronomy greenhouse, was planted on March 8, 1965. The plants were again grown in one gallon non-porous ceramic containers filled with fine sand; each container was provided with drainage. Nutrient solution was added three times per week. Soil moisture, temperature, and light were again maintained at suitable levels for good plant growth. Insects such as red spider and aphids were controlled with insecticides. Five seeds were planted one inch deep in each container, and they were subsequently thinned to one plant per container. Four replications of randomized complete blocks were used. The number seven leaf of each plant was measured for leaf area. The number seven leaf was used because this was found to be the longest leaf on most of the plants. The number of leaves, the tassel height, and the number of shoots were recorded. The roots of the plants were washed on June 8, 1965. The roots were measured for volume by a displacement of water in a 2000 ml. graduated cylinder. The leaves, stems, ears, and roots were placed in separate paper bags and oven dried at approximately 140° F for seven days. The plant part weights were recorded.

Experiment IV

The fourth trial was planted at the north agronomy farm in May 1965. The test was planted vive seeds per hill, with each hill forty inches apart; the distance between rows was forty-two inches. The hills were later thinned to three plants per hill. Plot size was two by four hills and plots were randomized within each of four replications. The plants were allowed to grow to maturity under the natural conditions. The leaf above the top ear was measured for leaf blade area. The plant and ear heights were recorded. As the plants matured in the fall the grain yields were taken. The per cent moisture was measured, and the yield was calculated on a dry weight basis. The amount and degree of lodging were recorded.

RESULTS AND DISCUSSION

One of the greatest hazards to crop production in the middlewest is drought. Corn is of a sub-tropical origin requiring a full growing season for its best development with adequate amounts of moisture, light, and temperature. The corn plant has taken its place among the leading crops in many regions of the world where drought is a major problem.

Experiment I

In these studies considerable differences were found among lines of corn in response to drought conditions as demonstrated by stress conditions of the summer of 1963. The daily rainfall and the maximum air temperature at the Agronomy Farm, Manhattan, Kansas, for the months of June, July, and August of 1963 and 1965 are shown in Appendix Tables 20, 21, and 22. Several of the single cross and inbred lines in the corn breeding nursery at Manhattan, Kansas, were severely affected by the drought of 1963. A few lines failed to produce seed while other lines produced enough seed under drought conditions to be of economic importance. Experiment I, Table 1, revealed that single crosses H28 x K55, H28 x K41, and K755 x K786 in consecutive order were statistically higher at the 1% level in grain yield than the other seven single crosses. A correlation between the yield of 1963 and the yield of 1965 was not significant for the hybrids, but there was a trend for the hybrid lines in 1963 to produce in the same manner in 1965. Information for the inbreds could not be statistically analyzed because of lack of information. Composite yields of the four replications of inbred lines were

Table 1. Yield, leaf rolling and top firing ratings of 10 single cross hybrids and 15 inbred lines grown at Manhattan, Kansas, 1963, Experiment I.

Entry	Yield lb/plot	Leaf rolling	Top firing
Hybrids			
H28 x K55	3.56	0.25	0.25
H28 x K41	3.55	0.50	0.00
K755 x K786	3.16	0.00	0.00
K41 x K742	2.45	2.25	0.00
K55 x K699	1.82	0.75	5.00
K11 x K708	0.65	2.25	0.00
K731 x K776	0.58	1.25	0.00
K63 x K740	0.46	1.00	0.00
K55 x K741	0.43	2.25	4.00
K724 x K731	0.03	3.00	0.00
L.S.D.	0.50	1.15	0.93
Inbreds			
H28	4.05	1.50	0.00
K755	3.55	0.00	0.00
K786	3.55	2.00	0.00
K41	3.38	3.75	0.00
K742	2.77	1.25	1.25
K55	2.12	0.50	5.00
K699	2.08	0.00	2.50
K11	0.73	0.25	2.50
K708	0.73	2.25	0.00
K776	0.64	1.00	0.00
K731	0.63	2.50	0.00
K741	0.36	2.00	0.75
K63	0.25	1.00	0.00
K740	0.25	2.25	0.00
K724	0.001	2.50	0.00
L.S.D.	No L.S.D.	1.08	0.92

recorded in the field; these are shown in Table 1. The inbred entries are ranked according to yield. The table shows that some inbreds have a trend to yield higher than other inbreds. And some high yielding inbreds have high yielding progeny in hybrid combination. Of the parent inbred lines, H28, K755, K786, K41, and K55 were among the top six of fifteen inbred lines in yield. A correlation between the yield of 1963 and the yield of 1965, Table 2, for the inbreds gave a negative trend, not statistically significant, for the yield of 1963 to decrease with an increase for the yield of 1965.

Table 2. Correlation coefficients among several characteristics measured in Experiments I and IV between yield and leaf rolling, yield and top firing, top firing and leaf rolling, yield of 1963 and yield of 1965, yield of 1965 and leaf rolling for 10 single cross hybrids and 15 inbred lines.

	Hybrid		Inbred	
Characteristics	Number of Observations	Correlation Coefficient	Number of Observations	Correlation Coefficient
Yield of 1963 and Leaf rolling 1963	10	-.72**	15	-.064
Yield of 1963 and Top firing 1963	10	-.26	15	.04
Top firing 1963 and Leaf rolling 1963	10	.018	15	-.54*
Yield of 1963 and Yield of 1965	10	.29	12	-.36
Yield of 1965 and Leaf rolling 1963	10	-.35	12	-.32

**Significant difference at the 1% level

*Significant difference at the 5% level

The leaf rolling data were taken primarily for the purpose of studying the relationship between leaf rolling and yield. Table 3 indicates that there were significant differences at the 1% level among the single crosses and inbreds in the amount of leaf rolling. K755 x K786, H28 x K55, and H28 x K41, in consecutive order, were the three single crosses with the least amount of leaf rolling. These same three single crosses also gave the highest amount of yield. The amount of leaf rolling of the inbred parents did not appear to be related with that of their single cross progenies. Correlation between yield and leaf rolling for the hybrids, Table 2, was negative and significant at the 5% level and indicated that plants with a high amount of leaf rolling had reduced yields. A correlation between yield and leaf rolling of the inbreds indicated that there was no correlation between the two. The correlation of leaf rolling, as measured in 1963, to the yield data of 1965 of the hybrids and inbreds exhibited a tendency, not statistically significant, for the yield to increase with a decrease of leaf rolling.

Top firing responses of lines are shown in Table 1. Significant differences at the 1% level were found among the single crosses and the inbred lines in the amount of top firing. The hybrids H28 x K55, H28 x K41, and K755 x K786 were among the seven single crosses displaying little or no top firing. The parent inbreds K755, K786, H28, and K41 exhibited no top firing, but K55 generally showed a high amount of top firing. The top firing and the leaf rolling data, Table 2, showed no correlation for hybrids, but there was a significant negative correlation at the 1% level between leaf rolling and top firing as expressed by the

Table 3. Analyses of variance of yield, leaf rolling, and top firing measurements of 10 single crosses and 15 inbred lines grown at Manhattan, Kansas, 1963. Experiment I.

Characteristics	Source of Variation	Hybrid df	Hybrid MS	Inbred df	Inbred MS
Yield	Replications	3	0.037	Insufficient information for yield analysis	
	Entries	9	8.91**		
	Error	27	0.146		
Leaf rolling	Replications	3	1.50	3	1.66
	Entries	9	4.18**	14	4.66**
	Error	27	0.78	42	1.44
Top firing	Replications	3	0.29	3	3.24**
	Entries	9	14.72**	14	8.58**
	Error	27	0.51	42	0.52

**Significant difference at the 1% level

*Significant difference at the 5% level

(The above designations will be used to indicate significance levels in all the following tables.)

inbred lines. This indicated that plants with high amounts of leaf rolling had no top firing and conversely plants with a high amount of top firing had little or no leaf rolling. The correlation of top firing and yield, Table 2, disclosed a slight tendency, not statistically significant, for the yield of the hybrids to increase as top firing decreased. The inbred lines showed no correlation. It appeared from the above test that single cross hybrids producing higher yields exhibited lower amounts of leaf rolling and top firing.

Experiment II

From Experiment I, differences were apparent in the ability of genetically different lines of corn to withstand drought and high temperatures in the field. It was desirable to know if genetic variations in morphological characteristics were associated with the ability of plants to resist or tolerate drought. One of these characteristics which was thought to be associated with plants ability to withstand drought was the volume of roots produced. To obtain such information the greenhouse study, Experiment II, was initiated.

The same ten single cross hybrids and fifteen inbred lines were chosen for this study because of their range in response to the effects of drought under field conditions. The plants were grown in the greenhouse for a period of about 16 weeks. The soil was removed from the roots by washing with water at the end of the period.

The root volume measurements are presented in Table 4. Statistically significant differences among hybrids at a 1% level were obtained. K11 x K708, K41 x K742, K63 x K740, K731 x K776, and H28 x K55, in consecutive order, were the upper five crosses in the amount of root volume produced, in Experiment II. The results of Experiment II and III in root volume were inconsistent. These results may have been influenced by soil moisture in the container or limited lighting effects. The inbred lines were not significantly different in root volume. Inbred H28 had the highest amount of root volume. The root lengths of the plants were not significantly different for hybrids or inbreds.

Table 4. Root volume yields and root lengths of 10 single cross hybrids and 15 single cross hybrids of corn in greenhouse study in the fall 1964, Experiment II.

Entry	Average Root Volume	Average Root Length
	cubic centimeters	inches
Hybrid		
K11 x K708	145	14.50
K41 x K742	106	15.38
K63 x K740	100	17.83
K731 x K776	98	19.00
H28 x K55	90	17.38
K755 x K786	87	19.17
K55 x K699	81	18.88
H28 x K41	76	21.75
K55 x K741	68	16.05
K724 x K731	45	16.05
L.S.D.	15.5	None
Inbred		
K11	63	16.25
K63	60	15.83
H28	60	16.38
K786	55	16.17
K742	55	16.75
K55	48	15.75
K708	47	18.33
K724	45	17.50
K41	45	19.67
K740	38	17.83
K741	38	13.75
K699	30	21.50
K731	30	22.25
K755	No plants	No plants
K776	No plants	No plants
L.S.D.	None	None

The leaf area of a plant may adversely affect its rate of transpiration. A plant with a smaller leaf area may have a greater chance to survive drought. The leaf blade area and leaf width differences, Table 5, were not found to be significant among the hybrid and inbred lines, but the leaf lengths were found to differ significantly at the 1% level in both the single crosses and the inbred lines. The three single crosses highest in leaf length, Table 6, were K63 x K740, H28 x K55, and K11 x K708. The three hybrids with greatest leaf blade area were K11 x K708, K755 x K786, and H28 x K55, and the one with least was K724 x K731. The cross, K724 x K731, also had shortest leaf length, and was the second from the lowest in leaf blade area; H28 x K55 was lowest. The three hybrids with the widest leaves were K11 x K708, K731 x K776, and K775 x K786. The inbred H28 had the longest leaf length and largest leaf blade area of the inbreds tested.

Differences in the number of leaves, Table 7, on the inbreds was statistically significant at the 1% level, but the differences among hybrids were not significant. The single crosses with the most number of leaves, Table 6, were H28 x K55, and K731 x K776. The cross, K724 x K731, had the smallest number of leaves. Over all K724 x K731 had the least leaf blade area, and in the yield test of 1963 was the lowest in yield of seed. In general, varieties that had a greater number of leaves and had a greater leaf blade area gave a larger yield in the drought test of 1963. The data for the inbred lines was somewhat inconsistent, but H28 which had the highest leaf blade area also gave the highest yield in the 1963 drought test.

Table 5. Analyses of variance of root volume, root length, total leaf length, leaf width, and leaf blade area of 10 single cross hybrids and 13 inbred lines in the greenhouse study fall of 1964, Experiment II.

Characteristics	Source of Variation	Hybrid		Inbred	
		df[1]	MS	df[1]	MS
Root Volume	Replications	3	2,373**	3	959
	Entries	9	1,819**	12	439
	Error	19	362	26	324
Root Length	Replications	3	19.83	3	12.47
	Entries	9	14.82	12	17.82
	Error	20	14.68	26	8.64
Total Leaf Length	Replications	3	8.75*	3	7.80
	Entries	9	20.17**	12	37.92**
	Error	20	1.80	27	8.15
Leaf Width	Replications	3	0.2867	3	0.0733
	Entries	9	0.2167	12	0.1192
	Error	19	0.1000	27	0.0811
Leaf Blade Area	Replications	3	196.22*	3	70.56
	Entries	9	100.73	12	89.16
	Error	19	58.10	27	56.55

[1]The degrees of freedom for error are reduced because of missing plots.

The height of the tassel, Table 7, of the inbreds differed significantly at the 1% level while the hybrids showed no significant difference. Of the ten single crosses, K55 x K741, K11 x K708, and H28 x K55, were the tallest three lines of the test, and K724 x K731 was the shortest line, Table 7. The tallest inbred line was H28. The ear height differences, Table 7, were significant at the 1% level among the inbreds, but not for hybrids. The plants producing the highest ears on the stalk, Table 8, were K11 x K708, H28 x K55, K63 x K740, and K731 x K776, and the inbred which produced the highest ear was H28. The data

Table 6. Average leaf blade area, average leaf length, average leaf width, and average number of leaves of 10 single cross hybrids and 15 single cross hybrids of corn in greenhouse study in the fall 1964, Experiment II.

Entry	Average Leaf Blade Area	Average Leaf Length	Average Leaf Width	Average Number of Leaves
	sq. inches	inches	inches	
Hybrid				
K11 x K708	50.41	30.38	2.38	11.50
K755 x K786	45.01	28.92	2.21	12.00
H28 x K55	41.06	30.75	1.63	12.50
K731 x K776	40.34	24.13	2.38	12.50
K55 x K699	39.49	26.06	1.97	12.50
K63 x K740	36.18	31.42	1.69	12.00
K41 x K742	36.68	29.31	1.78	11.50
K55 x K741	36.18	28.56	1.88	11.50
H28 x K41	35.42	29.00	1.74	11.25
K724 x K731	27.12	23.92	1.65	10.67
L.S.D.	None	1.79	None	None
Inbred				
H28	35.19	30.94	1.63	9.50
K742	33.58	27.31	1.75	12.00
K41	33.41	28.16	1.69	10.00
K708	30.35	23.67	1.65	11.67
K724	30.22	24.31	1.77	9.75
K11	28.24	24.75	1.63	10.50
K55	27.89	21.75	1.58	10.25
K786	27.54	23.50	1.67	12.00
K63	26.39	27.42	1.38	9.67
K731	23.63	21.94	1.52	9.00
K741	22.62	23.63	1.32	9.50
K740	21.13	26.58	1.13	12.33
K699	16.32	16.75	1.38	7.00
K755	No plants	No plants	No plants	No plants
K776	No plants	No plants	No plants	No plants
L.S.D.	None	3.23	None	1.21

Table 7. Analyses of variance of number of leaves, tassel height, number of ears, and ear height of 10 single cross hybrids and 13 inbred lines in the greenhouse study fall of 1964, Experiment II.

Characteristics	Source of Variation	Hybrid df[1]	Hybrid MS	Inbred df[1]	Inbred MS
Number of leaves	Replications	3	2.62	3	6.13
	Entries	9	1.23	12	6.22*
	Error	20	1.93	27	2.13
Tassel height	Replications	3	84.80*	3	28.34
	Entries	9	46.81	12	216.94**
	Error	20	25.61	21	15.02
Number of ears	Replications	3	0.6800	3	0.45
	Entries	9	0.5044	12	1.18**
	Error	20	0.3145	26	0.39
Ear height	Replications	3	13.15*	3	11.60
	Entries	9	3.83	10	26.06**
	Error	19	3.08	17	6.50

[1]Degrees of freedom for error are reduced because of missing plots.

on the number of ears per plot, Table 7, showed a significant difference at the 1% level among inbreds, and no significant differences among hybrids. The single crosses that produce two ears or more, Table 8, were K63 x K740, K755 x K786, K55 x K741, and K55 x K699; K724 x K731 produced the lowest number of ears. The inbred which produced two or more ears was K742. In these tests, number of ears per plant did not appear to be associated with ability to produce higher yields under stress conditions.

Table 8. Average tassel height, average ear height, and average number of ears of 10 single cross hybrids and 15 single cross hybrids of corn in greenhouse study in the fall 1964, Experiment II.

Entry	Average Tassel Height	Average Ear Height	Average Number of Ears
	inches	inches	
Hybrid			
K55 x K741	38.87	10.50	2.0
K11 x K708	38.50	14.25	1.0
H28 x K55	38.00	13.13	1.25
K755 x K786	33.91	10.83	2.0
H28 x K41	31.12	11.75	1.5
K731 x K776	29.25	12.00	1.5
K63 x K740	29.00	12.00	2.33
K41 x K742	28.75	11.00	1.75
K55 x K699	28.50	11.63	2.0
K724 x K731	28.00	10.50	.67
L.S.D.	None	None	None
Inbred			
H28	50.87	20.63	1.50
K741	38.50	14.00	.75
K55	35.83	12.88	1.50
K742	32.87	12.13	2.25
K724	32.43	10.63	1.00
K786	29.67	11.50	.33
K11	27.75	12.00	1.50
K708	26.17	10.88	.67
K41	26.08	10.50	1.33
K740	24.83	10.00	1.67
K63	24.50	6.83	0.00
K731	20.67	No ears	.75
K699	19.50	No ears	0.00
K755	No plants	No ears	No plants
K776	No plants	No ears	No plants
L.S.D.	4.47	3.30	0.71

Experiment III

The data for this experiment were taken for the purpose of providing additional information about root volume produced in the greenhouse. The root volumes, Table 9, were not found to be significantly different among hybrids and inbreds. It is noted in Table 10 that the three top hybrids in root volume, H28 x K55, K41 x K742, and K755 x K786 were also among the top four lines of yield in 1963. Root volume, Table 11, was significantly correlated at the 5% level with yield of hybrids in 1963. This indicated that as root volume increased a corresponding increase in yield of hybrids in 1963 was noted.

A correlation of root volume and yield in 1963 for inbreds showed a slight tendency, not statistically significant, for root volume to increase as yield of 1963 decreased. Root volume and the yield of 1965 correlations were calculated and there was a tendency, not statistically significant, for the hybrids and inbred root volumes to increase with the yield of 1965. The correlations of root volume and root weight were significant at the 1% level among the hybrids and inbreds. These correlations indicated that as root volume increased root weight also increased. The root weights, Table 9, differed significantly at the 1% level among hybrids, but no significant differences among inbred lines were noted. The top four hybrids in root weight were K41 x K742, K55 x K41, H28 x K55, and K755 x K786. Three of these crosses were also among the top four in yield in 1963.

A correlation of root weight and yield of 1963 for the hybrids, Table 11, showed a tendency, although not statistically significant,

Table 9. Analyses of variance of root volume, root weight, total leaf length, leaf width, and leaf blade area of 10 single crosses and 15 inbred lines grown in the greenhouse study the spring of 1965, Experiment III.

Characteristics	Source of Variation	Hybrid df[1]	Hybrid MS	Inbred df[1]	Inbred MS
Root volume	Replications	3	1,618	3	1,811
	Entries	9	5,568	13	1,740
	Error	19	3,854	19	1,850
Root weight	Replications	3	51	3	4.76
	Entries	9	172**	13	59.08
	Error	19	47	19	60.63
Total leaf length	Replications	3	1.09	3	32.71
	Entries	9	15.27	13	27.16
	Error	19	65.27	19	19.94
Leaf width	Replications	3	.2033	3	.0667
	Entries	9	.4755	13	.1546
	Error	19	.2389	19	.3126
Leaf blade area	Replications	3	110	3	2,262**
	Entries	9	422	13	95**
	Error	19	297	19	0.63

[1]Degrees of freedom for error are reduced because of missing plots.

for the root volume to increase with yield. The inbred lines showed no correlation. The hybrid with the least root volume and root weight was K742 x K731; it was also lowest in yield in 1963 and in root volume in the 1965 test. There was no correlation between the root volume of 1964 and the root volume of 1965 in the hybrids, but for the inbreds there was a slight association between the root volume of 1964 and the root volume of 1965 in the hybrids, but for the inbreds there was a slight association between the root volume of 1964 and the root volume of 1965.

Table 10. Average root volume, cubic centimeters, and average root weight of 10 single cross hybrids and 15 inbred lines of corn in greenhouse study in spring of 1965, Experiment III.

Entry	Average Root Volume	Average Root Weight
	cubic centimeters	grams
Hybrid		
H28 x K55	230	54.5
K41 x K742	227	60.7
K755 x K786	217	51.6
K55 x K699	178	49.1
K55 x K741	177	56.6
K731 x K776	160	47.3
K63 x K740	158	46.2
H28 x K41	143	43.7
K11 x K708	110	41.6
K724 x K731	103	39.6
L.S.D.	None	9.24
Inbred		
H28	140	51.9
K708	123	38.6
K41	113	42.0
H28	110	43.9
K11	110	46.1
K740	100	35.6
K741	100	35.8
K786	90	37.3
K731	78	36.8
K776	70	31.9
K724	60	34.7
K742	58	32.7
K55	45	32.5
K699	40	25.4
K755	No plants	No plants
L.S.D.	None	None

Table 11. Correlation coefficients among several characteristics measured in Experiments I, II, III, and IV between the root volume and yield 1963, root volume and root volume 1964, root volume and yield 1965, root weight and yield 1963, root volume and root weight, root weight and leaf blade area, root volume and leaf blade area for 10 single cross hybrids and 15 inbred lines.

	Hybrid		Inbred	
Characteristics	Number of Observations	Correlation Coefficient	Number of Observations	Correlation Coefficient
Root volume 1965 and Yield 1963	10	.64*	14	-.10
Root volume 1965 and Root volume 1964	10	.04	12	.28
Root volume 1965 and Yield 1965	10	.47	12	.11
Root weight 1965 and Yield 1963	10	.37	14	-0.027
Root volume 1965 and Root weight 1965	10	.89**	14	.91**
Root weight 1965 and Leaf blade area	10	.76*	14	.32
Root volume 1965 and Leaf blade area	10	.61	14	.35

The leaf blade area, Table 12, was calculated for one leaf on the plant. The leaf blade area, Table 9, of the hybrids demonstrated no significant differences, but the leaf blade area of the inbreds demonstrated significant differences at the 1% level. The leaf length of the hybrids and inbreds, Table 9, exhibited no significant differences. The hybrids with the longest leaves were K41 x K742 and H28 x K55, and these were among the top four in leaf length in 1964 test. Inbred H28 had the longest leaves in this test and the 1964 test, and inbred K63 was likewise in the top four of each test. The leaf widths, Table 9, were not significantly different for the hybrids and inbreds.

Root weight and leaf blade area, Table 11, were significantly correlated at the 5% level for the hybrids, but the inbreds showed a tendency, not statistically significant, for the root weights to increase with an increase of leaf blade area. The correlation of leaf blade area and root volume of the hybrids and inbreds exhibited a tendency for root volume to increase with leaf blade area. The number of leaves, Table 13, on a plant was significant at the 5% level for the hybrids. The top three lines were K11 x K708, K41 x K742, and H28 x K55 for the 1965 test. H28 x K55 was the line with the most leaves in 1964 test. The inbred lines were not significantly different in number of leaves.

The tassel height differences, Table 14, of the hybrids and inbreds were not significant. H28 x K55 ranked in the upper three in both 1964 and 1965 tests. The differences in number of ears per plant, Table 13, on a hybrid were significant at the 1% level. K55 x K699 maintained two ears both in the fall and spring tests. The other crosses

Table 12. Average leaf blade area, average leaf length, average leaf width, and average number of leaves of 10 single cross hybrids and 15 inbred lines of corn in greenhouse study in spring of 1965, Experiment III.

Entry	Average Leaf Blade Area	Average Leaf Length	Average Leaf Width	Average Number of Leaves
	square inches	inches	inches	
Hybrid				
K41 x K742	90.36	35.00	3.33	13.33
K55 x K699	83.66	29.68	3.50	13.25
K731 x K776	82.86	31.13	3.50	12.00
K55 x K741	81.33	31.33	3.33	12.67
H28 x K55	81.21	33.50	3.00	13.25
K755 x K786	65.27	29.17	3.08	12.67
K11 x K708	65.25	29.00	3.00	14.00
H28 x K41	62.59	33.50	2.75	11.33
K724 x K731	61.44	29.67	2.75	11.33
K63 x K740	60.13	31.62	2.44	13.25
L.S.D.	None	None	None	None
Inbred				
H28	56.87	32.00	2.25	13.00
K786	52.56	26.75	2.63	14.50
K776	48.50	29.50	2.00	12.00
K41	46.83	24.00	2.25	10.67
K741	45.31	24.00	2.50	12.00
K11	45.25	24.75	2.50	13.00
K708	43.25	25.25	2.13	11.00
K731	42.85	25.37	2.25	12.50
K55	41.98	21.13	2.31	10.50
K63	41.00	27.25	2.00	12.00
K699	40.00	24.00	2.50	10.00
K740	37.63	29.50	1.75	14.00
K724	37.34	19.75	2.56	10.25
K742	35.25	22.25	1.94	12.00
K755	No plants	No plants	No plants	No plants
L.S.D.	0.89	None	0.89	0.86

Table 13. Analyses of variance of number of leaves per plant, tassel heights, ear height, ear weight, number of ears, and stem and leaf weight of 10 single crosses and 14 inbred lines grown in the greenhouse study the spring of 1965, Experiment III.

Characteristics	Source of Variation	Hybrid df[1]	Hybrid MS	Inbred df[1]	Inbred MS
Number of leaves per plant	Replications	3	1.17	3	1.67
	Entries	9	2.18*	13	5.22
	Error	19	0.76	19	2.60
Tassel height	Replications	3	176.36	3	85.75
	Entries	9	99.54	13	316.78
	Error	19	116.10	19	216.77
Ear height	Replications	3	21.97	3	17.89
	Entries	9	37.22	13	49.69
	Error	19	19.52	19	150.95
Ear weight	Replications	3	224.52	3	47.32
	Entries	9	1,287.83	13	55.74
	Error	18	1,018.90	12	212.00
Number of ears	Replications	3	0.078	3	0.24
	Entries	9	0.598**	13	0.21
	Error	20	0.161	19	0.35
Steam and leaf weight	Replications	3	49.79	3	111.37
	Entries	9	776.03	13	144.82
	Error	19	482.54	19	294.44

[1]Degrees of freedom for error are reduced because of missing plots.

were inconsistent. The inbred H28 maintained the same number of ears and was in the top three of both tests. The ear height differences, Table 13, were not statistically significant for the hybrids or inbreds. H28 x K55 and K63 x K740 were among the top four in rank in 1964 and 1965 test. Inbred H28 ranked first and second for the 1964 and 1965 tests. The dry weight of the stems and leaves and the ear weights were recorded. The ear weight and the stem weight differences,

Table 14. Average tassel height, average ear height, and average number of ears of 10 single cross hybrids and 15 inbred lines of corn in greenhouse study in spring of 1965, Experiment III.

Entry	Average Tassel Height	Average Ear Height	Average Number of Ears
	inches	inches	
Hybrid			
K41 x K742	75.67	28.67	1.33
H28 x K55	63.63	27.75	1.25
H28 x K41	60.67	29.50	1.67
K55 x K699	59.25	25.37	2.00
K11 x K708	58.50	23.00	1.00
K55 x K741	58.17	21.00	1.00
K731 x K776	58.13	21.25	1.33
K755 x K786	57.50	20.33	1.00
K63 x K740	56.75	27.75	1.75
K724 x K731	56.17	25.00	1.00
L.S.D.	None	None	0.54
Inbred			
H28	73.50	32.50	1.50
K776	58.00	36.00	1.0
K63	55.00	28.50	1.0
K731	54.13	19.88	1.0
K786	49.25	20.50	1.25
K41	41.83	10.67	0.67
K11	41.50	18.25	1.0
K724	39.75	14.88	1.0
K742	37.75	15.00	1.0
K740	36.00	No ears	1.0
K55	35.25	14.67	1.0
K708	33.25	15.50	0.75
K741	32.00	16.00	1.0
K699	26.00	No ears	No ears
K755	No plants	No plants	No plants
L.S.D.	None	None	None

Table 13, were not significant for either inbreds or hybrids. K41 x K742, H28 x K55, and H28 x K41 were found to be in the top four ranks of the hybrids for stem and ear weight, Table 15. Among inbred lines H28 was first and K731 was second for ear weight and stem weight. It appears that the plant producing the greater stem weight may produce a larger ear weight.

The roots systems of the best hybrid, H28 x K55, and the poorest hybrid K724 x K731 and the parent inbred lines are shown in Plate I and Plate II, respectively.

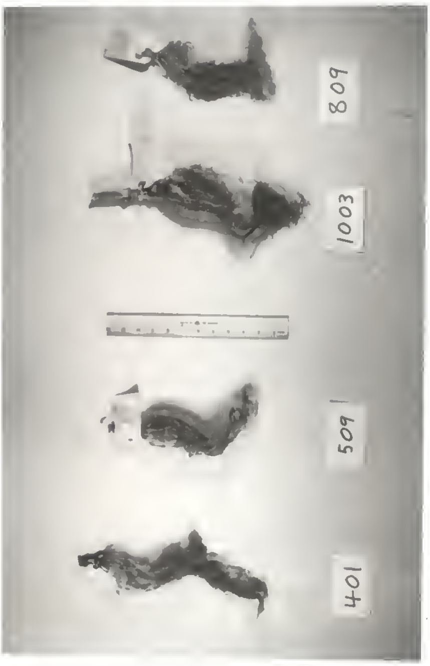
Table 15. Average ear weight and average stem weight of 10 single cross hybrids and 15 inbred lines of corn in greenhouse study in spring of 1965, Experiment III.

Entry	Average Ear Weight	Average Stem Weight
	grams	grams
Hybrid		
K41 x K742	108.23	110.23
K55 x K699	83.13	81.53
H28 x K55	76.07	94.33
H28 x K41	75.43	87.93
K55 x K741	75.27	96.33
K724 x K731	64.73	69.40
K731 x K776	61.85	79.23
K755 x K786	54.47	68.70
K11 x K708	40.90	56.00
K63 x K740	36.98	62.45
L.S.D.	None	None
Inbred		
H28	45.20	65.50
K731	44.17	59.25
K41	38.65	49.50
K786	36.28	50.45
K708	36.03	50.58
K55	35.43	42.25
K724	34.45	46.75
K742	33.93	44.10
K11	29.60	57.30
K740	29.50	49.70
K741	27.90	50.40
K63	27.80	50.40
K776	25.90	44.20
K699	No ear	22.70
K755	No plant	No plant
L.S.D.	None	None

EXPLANATION OF PLATE I

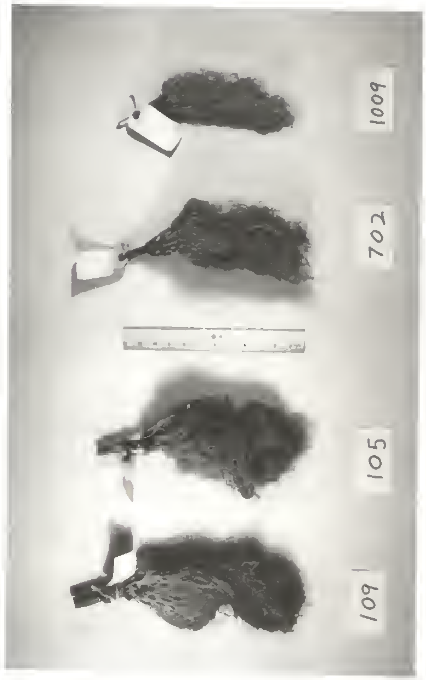
Root systems of single cross hybrid H28 x K55 and the parent inbreds, H28 and K55. Plots 410 and 910 are replplants made at a later date.

PLATE I



K55

H28

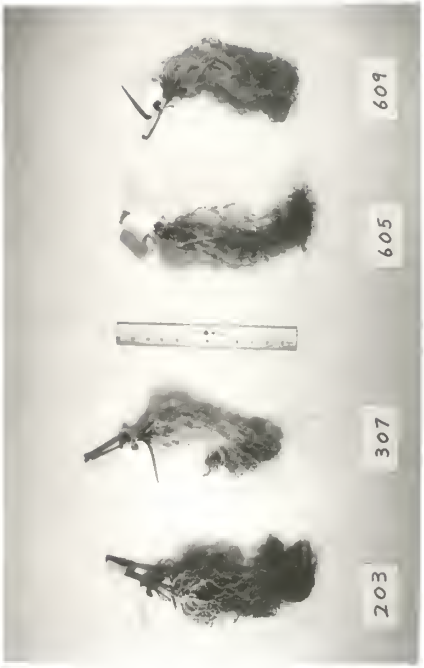


H28 x K55

EXPLANATION OF PLATE II

Root systems of single cross hybrid K724 x K731 and the parent inbreds, K724 and K731. Plot 106 is a replant made at a later date.

PLATE II



K731

K724

K724 x K731

Experiment IV

Experiment IV was conducted to gain additional information on yield and other responses of the corn plant to drought conditions in the field. The field test involved the same ten single cross hybrids and fifteen inbred parents previously tested. The analyses of variance for the data are shown in Tables 16 and 17. The yield variation among hybrids was significant at the 1% level and among inbreds the level of significance was 5%. H28 x K55 was the highest yielding single cross for both tests. In addition, K724 x K731 was the lowest yielding of the hybrids for both years. A correlation coefficient of the yield of 1963 under conditions and the yield of 1965, not under drought stress, indicated that there was a positive association between yields for the hybrids, although not statistically significant. The yields of the inbreds were not correlated to the single cross yields of either year. A correlation of root volume of the spring of 1965 and the yield of 1965 revealed a tendency for the hybrids and inbreds to have an increase of root volume with an increase of yield.

The leaf above the top ear was measured for length, width, and leaf blade area, Table 18. The leaf length variations were not significant for the hybrids but were significant at the 1% level for the inbreds. H28 had the longest leaf length of all the tests recorded. The leaf width differences were found to be significant at the 1% level both in the hybrids and among the inbreds: K731 x K776 and K55 x K699 had the widest leaves in Experiment III and IV and were in the upper four in Experiment II. The leaf width of the inbreds seemed somewhat inconsistent

Table 16. Analyses of variance for dry ear weight per plant, leaf width, leaf length, and leaf blade area of 10 single cross hybrids and 12 inbred lines grown at Manhattan, Kansas in the summer of 1965, Experiment IV.

Characteristics	Source of Variation	Hybrids		Inbreds	
		df	MS	df	MS
Dry ear weight per plant	Replications	3	.007	3	.002
	Entries	9	.030**	11	.005*
	Error	27	.007	33	.002
Leaf width	Replications	3	0.10	3	.04
	Entries	9	0.44**	11	.44**
	Error	27	0.08	33	.06
Leaf length	Replications	3	0.70	3	10.46
	Entries	9	5.47	11	53.36**
	Error	27	2.58	33	10.87
Leaf blade area	Replications	3	105.41	3	34.16
	Entries	9	309.53*	11	870.57
	Error	27	106.57	33	684.10

Table 17. Analyses of variance of plant height, ear height, percent plants lodged, and degree of lodging of 10 single cross hybrids and 12 inbred lines grown at Manhattan, Kansas, in the summer of 1965, Experiment IV.

Characteristics	Source of Variation	Hybrid		Inbred	
		df	MS	df	MS
Plant height	Replications	3	0.19*	3	.19
	Entries	9	0.58**	11	1.06**
	Error	27	0.06	33	0.08
Ear height	Replications	3	0.21	3	.083
	Entries	9	0.36**	11	.623**
	Error	27	0.08	33	0.85
Per cent plants lodged	Replications	3	877.33*	3	299.83
	Entries	9	949.11**	11	1,029.74**
	Error	27	293.17	33	288.73
Degree of	Replications	3	0.24	3	.23
	Entries	9	0.94*	11	1.55**
	Error	27	0.31	33	.42

Table 18. Average dry ear weight, average leaf blade area, average leaf length, and average leaf width of 10 single cross hybrids and 14 inbred lines of corn in agronomy farm study in summer 1965, Experiment IV.

Entry	Average Dry Ear Weight	Average Leaf Blade Area	Average Leaf Length	Average Leaf Width
	lbs/plant	square inches	inches	inches
Hybrid				
H28 x K55	.603	115.41	33.25	4.63
K55 x K699	.596	113.72	32.38	4.69
K63 x K740	.594	116.51	35.00	4.44
K41 x K742	.572	112.41	34.25	4.38
K11 x K708	.549	109.97	34.50	4.25
K55 x K741	.470	110.16	34.00	4.31
H28 x K41	.464	98.95	33.50	3.94
K755 x K786	.451	97.13	31.38	4.13
K731 x K776	.444	125.91	32.75	5.13
K724 x K731	.343	102.38	32.00	4.25
L.S.D.	.110	9.99	none	0.37
Inbred				
K724	.168	81.38	28.50	3.81
K11	.165	92.11	28.50	4.06
K708	.138	89.13	28.50	4.19
K41	.128	65.46	26.38	3.31
K699	.118	59.30	20.63	3.88
K741	.117	98.43	32.81	4.00
K63	.114	69.40	25.13	3.69
K786	.111	67.22	28.13	3.19
H28	.108	107.30	33.63	4.25
K55	.106	74.72	25.75	3.88
K740	.096	87.04	32.00	3.63
K731	.027	91.27	29.50	4.13
K742	No plants	No plants	No plants	No plants
K776	No plants	No plants	No plants	No plants
L.S.D.	.039	None	3.86	0.28

from one experiment to the other. From the data of leaf width and leaf length, the leaf blade area was calculated, Table 18. The leaf blade area variation was significant at the 5% level for hybrids, but was not significant for the inbreds. K731 x K776 ranked highest in leaf blade area in Experiment II and III. H28 x K55 was third in rank for leaf blade area in Experiment II and III. The inbred line H28 showed the highest amount of leaf blade area in all the tests cited.

Variations among hybrids and inbreds for plant height were significant at the 1% level. H28 x K55 ranked among the upper three crosses in all the tests for plant height. K63 x K740, H28 x K55, and H28 x K41 were the upper three crosses in plant height in Experiment IV, Table 19. K724 x K731 was the shortest hybrid in all the tests. The ear height differences among hybrids and inbreds were significant at the 1% level. K63 x K740, H28 x K55, H28 x K41, and K41 x K742 were in the upper five crosses of the ranking for ear height, Table 19. H28 was found to be in the upper two crosses for all the tests investigated. Although ear height may not have any advantage in enabling a hybrid to survive and produce under drought stress, it is noted that two of the higher producing lines also carried ears high on the stalk.

The amount of lodging is important for harvesting purposes. Variation in the per cent of plants lodged were significant at the 1% level for hybrids and inbreds. K63 x K41 and K755 x K786 showed the least lodging, Table 19. H28 x K55 showed a high per cent of lodging. Inbreds that showed no lodging were K708, K11, and K699. The degree of lodging was significant at the 5% level among hybrids and the 1% level among inbreds. K755 x K786, K63 x K740, H28 x K41, and K11 x K708 showed

Table 19. Average tassel height, average ear height, average per cent plants lodged, and average degree of lodging of 10 single cross hybrids and 14 inbred lines of corn in agronomy farm study in summer of 1965, Experiment IV.

Entry	Average Tassel Height	Average Ear Height	Average Per cent Plants Lodged	Average Degree of Lodging
	inches	inches		
Hybrid				
K63 x K740	6.46	3.91	4	1.25
H28 x K55	6.33	3.58	37	2.75
H28 x K41	6.25	3.52	11	1.75
K11 x K708	5.94	3.16	23	1.75
K41 x K742	5.85	3.41	34	2.25
K55 x K699	5.75	3.41	39	2.00
K731 x K776	5.73	3.33	36	2.00
K755 x K786	5.67	2.83	5	1.25
K55 x K741	5.42	3.08	50	2.50
K724 x K731	5.31	3.17	24	2.13
L.S.D.	0.32	0.37	22.36	0.54
Inbred				
H28	5.60	3.50	31	2.00
K731	5.33	2.92	45	2.88
K63	4.83	2.83	9	1.50
K724	4.71	2.41	30	2.00
K786	4.60	2.33	0	1.75
K741	4.46	2.33	41	2.13
K41	4.44	2.33	14	2.25
K11	4.35	2.33	0	1.00
K708	4.33	2.75	0	1.00
K740	4.31	2.25	11	2.00
K699	3.92	2.33	0	1.00
K55	3.83	2.08	27	2.63
K742	No plants	No plants	No plants	No plants
K776	No plants	No plants	No plants	No plants
L.S.D.	0.33	0.42	19.83	0.75

low degrees of lodging.

The results of this investigation indicate that H28 x K55 had the highest yields in Experiment I and IV and also produced the largest root volumes in Experiment III. The lowest yielding single cross in all the tests was K724 x K731. It also had the smallest root system in all tests. Top firing was observed line K55, and top firing tended to occur in most of the single crosses containing line K55.

The capacity of the corn plant to withstand drought is dependent in part upon the water gathering ability of the roots. A plant which can draw moisture from larger and wider areas can resist drought better. The plant with a small root system may be unable to penetrate the lower strata and surrounding areas and obtain moisture from the soil.

From these tests it appeared that sensitivity to leaf rolling may be an indicator of the lack of drought hardiness in single cross combinations of corn. Top firing seemed to be less detrimental to hybrid production under drought stress than leaf rolling. It is noteworthy that inbred H28 ranked high in many of the morphological characteristics measured and also occurred in the best hybrid combinations of lines in this study, such as H28 x K55.

It is recognized that the genetic combinations involved in this investigation represent only a very small part of the total genetic variability occurring in corn. The information obtained, however, reveals very definite differences due to genetic variation in the ability of hybrid combinations to survive and produce reasonable yields under severe drought conditions.

Future research on this subject should be directed toward better means of controlling the moisture level of the soil for the plant. A method of excluding moisture by nature could be used, and a source of irrigation water to prevent killing of the plants should be planned.

SUMMARY AND CONCLUSIONS

This study involves yield, leaf rolling, and top firing responses of ten single crosses and fifteen inbred lines of corn under drought stress in the summer of 1963. Additional information was obtained on plant characteristics including root volume, root weight, root length, leaf length, leaf width, leaf blade area, number of leaves, tassel height, ear height, number of ears, ear weight, stem and leaf weight in greenhouse studies in the fall of 1964 and spring of 1965. Field responses under less severe conditions were again studied in 1965.

The objectives of this study were to measure differences in drought response of genetically different lines of corn, and to study the effect of differences in root systems upon the ability of these lines to withstand drought stress. It was postulated that the plants with the greater root volume would be in the most favorable position to resist drought. This character might enable the plant to utilize more efficiently the moisture present in a given volume of soil than would otherwise be possible.

The results of the study indicated that H28 x K55 was superior to the other lines. H28 x K55 had highest yields of Experiments I and IV, and it produced the largest root volume in Experiment III. The

The lowest yielding single cross in all the tests was K724 x K731, and it also had the smallest root system in all tests. This would indicate H28 x K55 was more efficient in water utilization. Top firing was observed in line K55, and top firing tended to occur in most of the single crosses containing line K55.

The tests indicated that lines with a lower amount of leaf rolling and top firing produced larger yields under drought stress. Inbred H28 ranked high in many of the morphological characteristics measured and also occurred in the best hybrid combination of lines in the study.

The information obtained from this investigation indicates that considerable genetic variation exists within the corn population for ability to survive and provide some yield under severe drought stress. Some hybrid combinations tested failed to produce any seed yield under the conditions encountered in this study.

There is apparently a positive correlation between root volume and ability of a hybrid to yield under drought conditions. Positive relationships also existed between yield and some other plant characteristics measured, although these were probably of lesser importance as mechanisms of drought resistance.

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APPENDIX

Table 20. The daily rainfall and maximum air temperature at the North Agronomy Farm, Manhattan, Kansas, for the month of June 1963 and 1965.

Date	June 1963		June 1965	
	Temperature	Rainfall	Temperature	Rainfall
1	82	.25	86	1.36
2	87		84	
3	86		86	
4	88		82	
5	92		81	1.70
6	95		75	.13
7	98		86	
8	94		74	.61
9	96		77	.17
10	87	.08	85	.88
11	91		85	
12	90	.64	84	.57
13	96		80	
14	96	.97	73	.27
15	78	.18	79	
16	79		78	
17	80		76	
18	84	.21	80	
19	80	T	88	
20	90		86	
21	76		86	
22	84		83	
23	86		88	
24	91	.10	79	
25	94		84	
26	93	.10	84	.80
27	98	T	87	1.69
28	102		88	3.05
29	101		92	
30	99		81	
	Mean 89.7	Total 2.53	Mean 83	Total 11.27

Table 21. The daily rainfall and maximum air temperature at the North Agronomy Farm, Manhattan, Kansas, for the months of July 1963 and 1965.

Date	July 1963		July 1965	
	Temperature	Rainfall	Temperature	Rainfall
1	100		92	
2	98		87	.05
3	101		85	
4	100		86	.08
5	103		87	
6	99	.02	85	1.56
7	94		87	
8	91		90	
9	86		87	.11
10	73		85	.02
11	71	.21	82	
12	80	.51	94	
13	92	.10	92	
14	92		84	
15	90	.02	85	
16	97		95	
17	93	.21	95	T
18	100		85	.05
19	103		80	
20	96		91	.07
21	95	.02	96	
22	104	.03	97	
23	107		101	
24	105		85	
25	97		87	
26	96		89	
27	82		79	1.48
28	83	.02	81	.24
29	92	.01	85	
30	95		87	
31	96	T	81	
	Mean 93.9	Total 1.15	Mean 88	Total 3.66

Table 22. The daily rainfall and maximum air temperature at the North Agronomy Farm, Manhattan, Kansas, for the months of August 1963 and 1965.

Date	August 1963		August 1965	
	Temperature	Rainfall	Temperature	Rainfall
1	102	.02	86	
2	107		89	
3	91		96	
4	99		96	
5	107		88	
6	97	.10	92	T
7	97		84	.18
8	102		84	
9	87		88	
10	90	.04	89	
11	97		94	
12	93		98	
13	84	.02	94	
14	83		95	
15	94		92	
16	101		86	
17	85	.09	94	.08
18	66	1.06	74	1.14
19	79	.67	87	.14
20	89		78	
21	93		82	.03
22	98		70	.03
23	102		80	.02
24	95		84	1.11
25	99		95	
26	84		100	
27	105		86	
28	93	.03	80	
29	88		92	.05
30	90		94	T
31	84		71	.17
Mean	92.9	Total 2.05	Mean 87.7	Total 2.95

DROUGHT AND HEAT RESPONSES IN SELECTED HYBRID AND INBRED LINES OF CORN

by

MELVIN VERN SPLITTER

B. S., Kansas State University, 1965

AN ABSTRACT OF A MASTER'S THESIS

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The purpose of this study was to measure differences in drought response of genetically different hybrids of corn, and to study root systems in relation to drought resistance. Ten single cross hybrids of corn and fifteen inbred parents used in this drought study were obtained from the Corn Project of Kansas State University. The ten single cross corn hybrids were as follows: H28 x K41, H28 x K55, K11 x K708, K41 x K742, K55 x K699, K55 x K741, K63 x K740, K724 x K731, K731 x K776, and K755 and K786. The inbred lines were H28, K11, K41, K55, K63, K699, K708, K724, K731, K740, K741, K742, K755, K776, and K786.

The investigation was divided into four parts including two field studies and two greenhouse studies. The study involved yield, leaf rolling, and top firing responses of the lines under drought stress in the summer of 1963. Additional information obtained on plant characteristics included root volume, root weight, root length, leaf length, leaf width, leaf blade area, number of leaves, tassel height, ear height, number of ears, ear weight, stem and leaf weights in the greenhouse studies in the fall of 1964 and spring of 1965. Field responses under less severe conditions were again studied in 1965.

The results of the study indicated that H28 x K55 was superior to the other hybrids. H28 x K55 had the highest yields in Experiments I and IV, and it produced the largest root volume in Experiment III. The lowest yielding hybrid, which also had the smallest root volume in all the single crosses, was K724 x K731. This would indicate H28 x K55 was more efficient in water utilization. Top firing was observed in line K55, and top firing tended to occur in most of the single crosses containing line K55.

The test indicated that lines with a lower amount of leaf rolling and top firing produced larger yields under drought stress. Inbred H28 ranked high in many of the morphological characteristics measured and also occurred in the best hybrid combinations of lines in the study.

The information obtained from this investigation indicates that considerable genetic variation exists within the corn population for ability to survive and provide some yield under severe drought stress. Some hybrid combinations tested failed to produce any seed yield under the conditions encountered in this study.

There is apparently a positive correlation between root volume and ability of a hybrid to yield under drought conditions. Positive relationships also existed between yield and some other plant characteristics measured, although these were probably of lesser importance as mechanisms of drought resistance.