FACTORS AFFECTING THE SUCCESS OF POLLINATION IN CORN

by

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TABLE OF CONTENTS

INTRODUCTION

Adverse climatic conditions during the critical flowering period of corn, *Zea mays* L., represent one of the greatest hazards to corn production in the Great Plains area. High temperatures and extreme desiccation, or both, may blast the entire tassel or kill the pollen grains after they are shed, or may otherwise interfere with pollination by causing the silks to dry out rapidly thus losing their receptiveness to pollen. This interference with the pollination process is reflected in poorly pollinated ears at harvest and consequently a reduction in yield of grain.

Previous work at the Kansas Agricultural Experiment Station has shown that hybrids that are resistant to leaf firing have an advantage in yield of grain over susceptible types during years when droughts occur. It appears that the reduction in yield may be due to interference with normal fertilization as well as injury sustained by the vegetative portion of the plant. Methods that will aid in the selection of lines and hybrids that pollinate satisfactorily and consistently produce profitable yields are needed in the corn breeding programs in the Great Plains area where droughts are frequent.

The objects of this study were (1) to study the length of time silks remain receptive to pollen; (2) to determine the affect of high temperatures on the success of pollination; and (3) to determine whether inbred lines differ in the ability of their pollen to effect fertilization.

REVIEW OF LITERATURE

No extensive studies on the length of time corn silks remain receptive to pollen are recorded in the literature. Crozier (1888) reported that where silks were held until well started they set perfect ears when pollinated. He also reported that cutting off the silks did not prevent future pollination on new growth. He concluded that the forked apex of the silk is not alone receptive. Kiesselbach (1922) stated that the age of unfertilized silk was seldom a problem in experiments involving artificial pollination since the silks were receptive to pollen before emerging from the husks and for approximately two weeks thereafter. More recently, work on the length of receptivity of stigmas has been reported for other crops. Anthony and Harlan (1920) worked on the period of receptivity of barley stigmas. In these investigations, flowers were pollinated each day for six days. The percentage of fertilizations increased for two days, but from this time there was a gradual decrease until, on the sixth day, no pollinations brought about fertilization. Atabekova (1928) reported successful setting of seeds in wheat where fresh pollen was used on stigmas up to eight and nine days old. Dutt and Krishnaswamy (1931) working with sugar cane flowers found the stigmas receptive 24 hours before emergence and a few grains set on stigmas up to 11 days old. Sorghum stigmas were found by Stephens and Quinby (1934) to be receptive at least 48 hours before the flowers bloomed and eight to 16 days after blooming.

The fact that staminate flowers of maize produces a superabundance of pollen where conditions are at least partially favorable is shown by the fact that during the height of the pollinating season the soil surface of a corn field usually takes on a yellowish cast due to the abundant pollen shed by the tassels. These vast quantities of pollen produced by the corn plant have often been referred to as the "gold dust" of the corn belt. According to Hunt, (1912), Lazenby estimated that about 45,000 pollen grains are produced for each ovule of a dent variety; and Sargent estimated the ratio to be at least 9,000 to 1. Weatherwax (1916) stated that a ratio of 15,000 to 1 is probably low enough and that it may well be as great as 150,000 to 1. Martin (1937) reported that adverse weather conditions prevailing during the pollinating period may seriously reduce the amount of pollen produced. During the drought of 1936 he studied the staminate flowers of corn and found that many of the spikelets were killed outright; in others the swelling of the lodicules, elongation of the filaments, and formation and opening of the anther pores was inhibited. In many cases, however, the pollen, which had developed while still enveloped by the leaves, survived. Studies on the effect of external factors on pollen viability, germination, and tube growth for various pollens have shown in general that low humidity and high temperature cause low pollen germination. The degree to which various extremes of humidity and temperature affect pollen germination varied considerably with the species according to Knowlton (1922), Buckholz and Blakeslee (1927), Gotoh (1931), Noguchi (1931), Poole (1932) and Smith and Cochran (1935). The work of Knowlton (1922) is of special interest in this study since he worked with corn pollen. He reported some unpublished work on the longevity of corn pollen by Andronescu at the University of Illinois. Andronescu found that corn pollen stored outside lost 48 percent of its moisture in two hours and 52 percent in 24 hours. Since he found that pollen lived longer at higher humidities, he concluded that death was caused by desiccation. Knowlton found that, although corn pollen is wind-blown and seemingly dry, the moisture content is very high. His determinations showed a range in moisture content from 50 to 65 percent, depending upon the amount of moisture in the air, the maturity of the tassel, and the amount of water available to the plant. He concluded that when corn pollen is subjected to normal atmospheric conditions, drying out is undoubtedly the main factor which determines the duration of its vitality. Coffman (1937) studying the factors that influence seed set in oat crossing found that very few seeds were set when temperatures got above 95°F. He concluded that the reason for poor results under conditions of high temperatures and low humidity was that the pollen and stigmas dried out so rapidly that the pollen in many cases was unable to germinate. When it was able to germinate, the pollen tube was never able to reach the ovary before the stigmas had dried up. The failure to get seed set was believed to be due more to the rapid drying out of both pollen and stigmas than to the lethal effect of high temperatures.

A number of workers have attempted to correlate the temperature and rainfall during June, July, and August with the grain yield of corn for that season. Hodges (1931) and Robb (1934) using long time averages obtained highly significant correlations between temperature and rainfall during July and yield of grain. Rose (1936), studying 58 climatic factors, most of them for monthly periods from 1914 to 1932, found temperature and rainfall during July closely correlated with yield, the temperature being more important than rainfall. Smith (1914) found the period from mid-July to mid-August to be the most critical period for corn as far as temperature and rainfall were concerned. Since the critical flowering period of corn usually occurs during the latter part of July and the early part of August, the reduction in yield due to adverse climatic conditions during this period may be due to interference with normal fertilization as well as injury to the vegetative portion of the plant.

Drought may be of two main types: (1) atmospheric drought and (2) soil drought. Atmospheric drought may produce rapid wilting or even desiccation of plant tissues through the action of hot, dry winds even though there is sufficient soil moisture available. Soil drought occurs when the soil moisture is not sufficient to replace that lost by transpiration, causing the plant to wilt permanently. Probably the most severe damage to growing crops results from a combination of these two types of drought. The term "drought" has been defined by Kincer (1919) as 30 consecutive days, or more, without 0.25 inch of rainfall in 24 hours during the period March to September inclusive. This, however, is not a satisfactory definition from the standpoint of growing crops since temperature and humidity relationships so characteristic of severe droughts are not taken into consideration.

Probably the best definition of drought resistance was that given by Maximov (1926) who described it as being the capacity of a plant to endure a state of permanent wilting with a minimum of injury. Efforts to classify plants as to their relative drought resistance have usually been based on the amount of injury sustained when subjected to extreme drought conditions. This includes both soil and atmospheric drought produced either artificially or occurring naturally.

Attempts to correlate certain morphological characteristics of plants growing normally in arid or semi-arid regions with drought resistance have been made by various workers. The results, however, have not been entirely satisfactory. Pool (1923) in his studies on leaves of xerophytes and mesophytes concluded that the degree of correlation between habitat xerophytism and leaf morphology is rather low and uncertain. Haber (1938) studying drought resistance in inbred lines of sweet corn, found that the number of vascular bundles, number of stomata, and root volume all failed to give any indication of the drought reaction of the lines. The ability of a plant to withstand permanent wilting was held by Maximov (1929) to be explainable on the basis of conditions within the cells, such as, increase in the osmotic pressure, and modifications in the protoplasm that increase its waterholding capacity. External changes (xeromorphism) that further aid in conserving water are merely manifestations of these more fundamental inner physiological changes. Thus the problem of drought resistance is transferred from the phase of morphology to the field of physiology and biochemistry.

A large part of the early work on drought resistance was made from the standpoint of water requirement and rate of transpiration of different plants. Briggs and McLane (1914), Miller (1916 and 1923), and Kiesselbach (1926 and

1929) were unable to find significant differences in water requirement ratios between drought resistant and drought susceptible plants. Miller and Coffman (1918), Pool (1923), and Haber (1938) concluded that the transpiring power of a plant was no indicction of its drought reaction.

The ability of a plant to reduce the available water content of the soil in which it was growing has been studied by Briggs and McLane (1912), Tumanov (1926 and 1929), Shantz (1927) and Kondo (1931). In general their results seem to indicate that the actual differences were less than expected and were insignificant in comparison with the range in moisture retention exhibited by different soils. Thus the only remaining location of the cause for drought resistance seems to be within the plant itself, i. e., in the cell protoplasm.

Physiological studies on the protoplasm of drought resistant and drought susceptible plants have resulted in some rather interesting and promising findings. Shreve (1916) attributed the ability of cactus to resist water loss to the imbibitional forces of hydrophyllic colloids which he believed were more abundant in plants of drier regions. However, he reported no quantitative studies on colloids of different plants. Newton and Martin (1930) believed that the imbibitional properties of the cell sap were very important in water retention under drought conditions. They found that the osmotic pressure of the cell sap of crop plants varied with the physiological scarcity of the water but that it was not a reliable index of drought resistance. However, bound water content of the cell sap was much more dependable. They were able to arrange cultivated wheats and several grasses in order of their drought resistance on this basis. About the same time a Russian worker, Korikov (1931), reported he was able to classify a number of wheat varieties as to relative drought resistance on the basis of bound water determinations. Holbert and

Frye (1933) grew heat resistant and heat susceptible inbred lines of yellow dent corn under conditions of artificial drought. They found that the bound water content of the heat resistant lines increased as the heat and drought continued, with temperatures ranging from 95° to 105°F. At the same time the total water content decreased. Heat susceptible strains, on the other hand, showed very little, if any, increase in amount of bound water under similar conditions, and in some cases the bound water content decreased significantly. The results obtained with bound water determinations would appear to warrant further study on this phase of drought resistance.

MATERIALS AND METHODS

The corn used in these studies was for the most part taken from the breeding material of the corn improvement project at Manhattan, Kansas. The material was classed as drought resistant or drought susceptible on the basis of its differential resistance to leaf firing under heat and drought conditions in the field.

Six inbred lines, three resistant to leaf firing and three susceptible to leaf firing together with the 15 possible single cross combinations among them were used in studying the length of time silks remain receptive to pollen. Two plantings of the material were made, one under dry land conditions at the Agronomy Farm where neither moisture nor temperature was controlled and the other under irrigation at the Soil Conservation Service Nursery where soil moisture was not a limiting factor. Plantings were made at weekly intervals for a period of one month to insure a spread of emerging silks over a period of at least three weeks. The ear shoots were covered with parchment bags before the silks appeared in order to prevent natural pollination. The upper shoot was used in these studies, but all were covered to prevent any possible change in the physiology of the silks of the upper shoots that might result from fertilization of the lower ones. The shoots were examined every other day for the first appearance of the silks. As soon as the silks had emerged, the date was marked on the parchment bag. This procedure was continued until most of the plants had silked out and while there was still sufficient pollen available to accomplish fertilization. All the silks were exposed on the same day by removing the parchment bags and exposing the silks to wind-blown pollen. By this procedure, silks which had emerged first were held the longest and all of the silks of any one age were subject to the same environmental conditions. The material at the Agronomy Farm was planted in a crossing block and that in the irrigated nursery beside the breeding material so that sufficient pollen was available when the silks were exposed. To insure sufficient pollen reaching each newly exposed silk, however, pollen was gathered in pollinating bags from surrounding tassels, and a little pollen dusted on each silk. Since the pollen parent in the crossing block at the Agronomy Farm was the single cross, WF9x38-11, pollen was taken from the same single cross in the irrigated nursery and used in dusting the newly exposed silks at that location in a similar manner. Any differences in fertilization due to different kinds of pollen in the irrigated nursery were thereby largely eliminated.

In measuring the differential length of time the silks remained receptive to pollen, the amount of seed set on each ear was estimated at harvest. The ears were placed into ten grades on the basis of kernels set. A grade of one indicated one to ten percent of kernels set, a grade of ten indicated 91 to 100 percent set, the eight intervening grades referring to corresponding percents of kernels set.

An abundance of shoots for the receptivity of silk studies made it possible to determine the rate and persistence of silk growth under irrigated and dryland conditions when cut back at regular intervals. Three plants of each inbred line and single cross were selected at random on which the silks were just beginning to emerge. These plants were tagged and every second day the amount of new growth was first measured in centimeters and then clipped back to the tip of the husks with a pair of scissors. This procedure was continued until no further growth of these silks occurred. Data on the persistence of silk growth was obtained for the single crosses at both locations and for only the inbreds at the irrigated nursery. The inbred lines growing under dryland conditions were so slow to silk out that it was necessary to use all the silks obtained for the receptivity of silk studies.

During the summer of 1940, 15 inbred lines were grown in the irrigated nursery for the purpose of increasing seed stocks. Temperatures were quite high and variable during the period in which these lines were being pollinated. Since each tassel bag was stamped with the date on which the pollination was made, an excellent opportunity was afforded for observing the effect of high temperatures on the success of pollination. The success of pollination was determined by estimating the percent of seed set on each ear at harvest. The results obtained were correlated with the maximum temperature recorded for the day on which the pollination was made. Temperature records were obtained from the United States Weather Bureau report for Manhattan, Kansas.

Similar data were again taken in the irrigated nursery in 1941 on all selfing material. This material represented nearly all the lines of the Kansas Agricultural Experiment Station together with the more important lines of most of the other states where corn breeding work is being done. Thus an extremely wide range of material was represented. Temperature records were obtained for 1941 from a recording hygrothermograph located in the nursery. These results also were correlated with the maximum temperature recorded.

An attempt to determine the differential fertilizing ability of pollen of

25 inbred lines grown in the irrigated nursery was made during the summer of 1941. On the basis of their resistance to leaf firing, 14 of these lines were classed as resistant and 11 as susceptible. Five of the best tassels of each line were bagged. The following morning each tassel bag was removed and the pollen placed on silks of the single cross, WF9x38-11. The ear shoots had been covered with parchment bags prior to silk emergence to prevent natural pollination. Only shoots showing a good growth of silk and no corn ear worm damage were used. An index or measure of fertilizing ability of the various pollens was made at harvest by placing the ears into ten grades based on the percent of seed set on each ear.

All data were treated statistically. The methods of calculating the analysis of variance and correlation coefficients were taken from Snedecor (1940).

EXPERIMENTAL CONDITIONS

The daily maximum and minimum temperatures together with precipitation at Manhattan, Kansas, for the months of July and August, 1940, are given in Table 1. 1/ July was the ninth driest and eighth hottest month on record. The first week of August was a continuation of these extreme conditions. This was followed by heavy rains and lower temperatures during the next three weeks ending the severe summer drought. Most of the extreme temperatures during these two months occurred in the midst of the pollinating season. This offered an excellent opportunity for studying the effect of temperature on the success of pollination.

1/ Weather records for Manhattan from the U. S. Dept. of Commerce, Weather Bureau.

Table 1. Daily maximum and minimum air temperatures together with the precipitation for the two-month period, July and August, 1940, at Manhattan, Kansas.

Date	July			August		
	Temperature		Precipitation	Temperature		Precipitation
	Max. °F.	Min. °F.	In.	Max. °F.	Min. °F.	In.
1	92	68	.00	104	77	.00
2	86	66	.00	104	75	.00
3	83	59	.00	99	73	T.
4	86	51	.00	102	72	T.
5	88	61	.00	92	70	.00
6	92	60	.00	90	61	.08
7	95	63	.00	94	64	.00
8	98	65	.00	86	65	T.
9	100	74	.00	87	66	.98
10	101	70	.00	86	64	.00
11	96	78	.00	82	64	.00
12	82	66	.00	91	69	T.
13	85	53	.00	96	71	.00
14	96	58	.00	88	66	.10
15	88	71	.00	83	69	1.00
16	94	70	.00	84	68	.99
17	101	70	.00	81	69	.32
18	104	78	.00	73	62	T.
19	106	76	.00	77	51	.00
20	95	74	.00	79	53	.00
21	97	69	.00	84	59	.00
22	98	73	T.	86	65	.02
23	104	74	.00	78	67	.00
24	109	76	.00	91	68	.01
26	107	78	.00	88	67	1.04
27	100	72	.37	81	63	.24
28	106	80	.01	86	61	.00
29	109	81	.00	84	65	.00
30	106	80	.00	85	60	.00
31	106	78	.00	87	60	.00
Total			0.38			4.72
Mean	97.3	70.1		88.2	65.6	

Weather data for July and August, 1941, were collected for use in these studies at each of the two locations, Agronomy Farm (dryland) and Soil Conservation Service Nursery (irrigated). Maximum and minimum temperatures were obtained from recording hygrothermographs placed in shelters in the corn at each location. Precipitation data for the Agronomy Farm were obtained from the weather records of the Agronomy Department and for the Soil Conservation Service Nursery from the weather records of the Soil Conservation Service. The 1941 daily maximum and minimum temperatures together with precipitation for the Agronomy Farm are given in Table 2 and for the Soil Conservation Service Nursery in Table 3.

Although extremes in temperatures occurred during July and August, the temperatures in 1941 were in general considerably lower than for the same period in 1940. Lack of rainfall during the greater part of July resulted in a midsummer drought. High humidity during this period together with not too extreme temperatures minimized the damage which might otherwise have occurred to the corn crop. Temperatures at the Agronomy Farm were considerably higher than those at the Soil Conservation Service Nursery. Ample soil moisture at the latter location probably resulted in more rapid evaporation from the soil surface and more rapid transpiration from the plants, consequently, a cooler layer of air surrounded the plants.

Evaporation data were obtained at both locations from white porous cup atmometers placed in duplicate in the corn at ground, ear, tassel, and above tassel heights. Readings were made at three-day intervals. Evaporation data from the Agronomy Farm are given in Table 4 and from the Soil Conservation Service Nursery in Table 5.

As would be expected, the evaporation at the Agronomy Farm was considerably greater than that at the Soil Conservation Service Nursery. However, a

Table 2. Daily maximum and minimum air temperatures together with the precipitation for the two-month period, July and August, 1941, at the Agronomy Farm (dryland), Manhattan, Kansas.

Date	July			August		
	Temperature		Precipitation	Temperature		Precipitation
	Max. °F.	Min. °F.	In.	Max. °F.	Min. °F.	In.
1	100	72	.00	104	70	.00
2	92	64	.62	105	68	.00
3	69	60	.00	109	74	.00
4	82	58	.00	112	72	.00
5	85	61	.00	99	70	T.
6	86	67	.13	105	70	.00
7	89	76	.00	106	66	.00
8	92	72	.00	100	70	.00
9	104	74	.00	104	72	.00
10	103	73	.00	108	74	.00
11	92	66	.00	110	82	1.57
12	84	57	.00	111	76	.10
13	79	57	.00	76	70	.00
14	86	63	.00	77	69	.00
15	91	67	.00	94	66	.00
16	98	62	.00	97	67	.00
17	104	68	.00	90	66	.30
18	95	70	.00	89	72	.00
19	98	57	.00	96	62	.00
20	103	60	.00	92	65	.01
21	112	68	.00	96	70	.00
22	110	78	.00	100	66	.00
23	111	78	.00	90	66	.21
24	106	78	.00	94	68	.00
25	110	68	.00	100	74	.35
26	92	74	1.02	78	68	.00
27	95	75	.00	80	66	.00
28	98	78	.04	89	62	.00
29	104	81	.00	96	72	.00
30	96	74	.18	98	76	.00
31	106	71	.00	96	80	.00
Total			1.99			2.54
Mean	95.7	68.7		96.9	70.0	

Table 5. Daily maximum and minimum air temperatures together with the precipitation for the two-month period, July and August, 1941, at the Soil Conservation Service Nursery (irrigated), Manhattan, Kansas.

Date	July			August		
	Temperature		Precipitation	Temperature		Precipitation
	Max. °F.	Min. °F.	In.	Max. °F.	Min. °F.	In.
1	86	70	.00	96	73	.00
2	73	62	.30	99	71	.00
3	74	60	.20	101	69	.00
4	85	72	.00	92	69	.00
5	83	69	.00	94	67	.00
6	89	71	.53	96	70	.00
7	93	70	.00	95	72	.00
8	99	74	.00	95	72	.00
9	99	76	.00	99	80	.00
10	90	68	.00	99	70	.00
11	83	60	.00	76	67	.00
12	79	59	.00	75	65	1.66
13	80	64	.00	90	66	.28
14	86	64	.00	90	68	.00
15	90	68	.00	87	70	.00
16	97	68	.00	96	68	.00
17	90	57	.00	82	62	.00
18	89	59	.00	86	72	.99
19	88	67	.00	83	62	.00
20	97	74	.00	87	66	.00
21	99	72	.00	99	72	.00
22	100	72	.00	94	69	.00
23	99	68	.00	91	70	.07
24	95	69	.00	89	66	.00
25	87	75	.00	76	63	.44
26	91	77	.00	76	64	.00
27	98	82	.51	87	70	.00
28	103	77	.00	94	76	.00
29	94	70	.05	95	77	.00
30	94	69	.00	91	73	.00
31	95	69	.00	90	70	.00
Total			1.59			3.44
Mean	90.4	68.8		90.1	69.3	

Table 4. Evaporation from white porous cup atmometers placed at the ground, ear, tassel, and above tassel heights during the two-month period July and August, 1941, at the Agronomy Farm, (dryland), Manhattan, Kansas. All readings made in duplicate and recorded at three-day intervals.

Date	Total evaporation (cubic centimeters)			
	Ground 12 in.	Ear 30 in.	Tassel 72 in.	Above tassel 108 in.
July				
3	62.4	63.5	84.7	90.1
6	84.3	90.1	111.2	118.6
9	130.9	134.7	159.4	172.8
12	123.8	127.0	158.6	171.3
15	95.5	92.4	116.6	120.1
18	143.6	129.0	166.7	210.6
21	152.1	136.3	173.6	231.0
24	241.0	212.5	273.8	336.0
27	105.2	87.8	110.1	146.3
30	133.6	120.9	165.6	217.5
August				
2	98.9	86.2	110.9	147.4
5	163.2	133.2	167.5	209.0
8	140.9	122.0	153.2	177.1
11	195.6	177.5	212.2	264.5
14	41.2	52.4	64.7	113.2
17	106.6	106.1	132.8	166.3
20	68.9	70.0	83.2	110.9
23	75.1	72.8	86.1	109.0
26	65.8	65.0	73.2	99.0
29	109.3	108.2	138.6	160.2
September				
1	98.9	106.6	138.6	172.8
Total	2445.3	2292.1	2880.3	3542.4
Mean	116.4	109.1	137.2	168.7

Table 5. Evaporation from white porous cup atmometers placed at the ground, ear, tassel, and above tassel heights during the two-month period, July and August, 1941, at the Soil Conservation Service Nursery, (irrigated), Manhattan, Kansas. All readings made in duplicate and recorded at three-day intervals.

Date	Total evaporation (cubic centimeters)			
	Ground 12 in.	Ear 30 in.	Tassel 72 in.	Above tassel 108 in.
July				
3	38.0	44.4	71.8	80.6
6	59.6	69.6	99.6	123.1
9	76.0	82.1	122.8	164.6
12	81.0	82.1	124.6	158.8
15	45.6	51.3	75.6	102.6
18	84.4	87.0	117.8	159.6
21	72.6	87.4	107.9	165.8
24	117.0	145.9	164.6	235.0
27	44.1	47.9	77.5	104.1
30	90.8	124.2	137.6	194.2
August				
2	46.0	54.7	81.0	112.5
5	69.9	81.7	122.0	162.6
8	71.0	80.6	118.2	159.2
11	115.0	109.4	158.8	194.6
14	36.8	42.6	52.0	76.0
17	79.0	82.8	118.2	149.0
20	42.6	50.2	63.8	115.1
23	43.3	48.2	60.8	115.1
26	42.2	44.8	66.9	84.4
29	80.6	91.6	117.4	148.6
September				
1	92.7	100.0	136.4	158.8
Total	1428.2	1608.5	2195.3	2931.4
Mean	68.0	76.6	104.5	139.6

comparison of PLATES I and II shows an interesting difference between the two locations with regard to the evaporation at the different levels. Under irrigated conditions there was an increase in evaporation at each level from the ground upward. The evaporation rates at the different levels in the corn growing under dryland conditions at first were similar to those under irrigation. That is, the evaporation gradient increased for each level from the ground upward. Readings on the 15th of July, however, showed the evaporation at the ground surface to be greater than that at the ear height, the next level higher. At this time, the soil was becoming very dry and the lower leaves were firing badly. The evaporation at the ground surface remained higher than that at the ear height until heavy rains during the middle of August thoroughly wet the soil surface decreasing the evaporation at the lower (ground) height enough so that it was about the same as that at the ear height for the remainder of the season.

EXPERIMENTAL RESULTS

Persistence of Silk Growth

Data on the persistence of silk growth for the inbred lines are given in Table 6 and analysis of variance in Table 7. The data show that in every case growth was much greater during the first two-day period than for any subsequent period. The rapidity with which growth rate tapered off was greatest from the first to the second two-day period. This rapid decline may have been due to the injury sustained by the silks from clipping, although under ordinary field conditions the rate of growth of silks is very rapid during the first few days following emergence from the husks. The lines showed a range in growth of 8.0 cm. to 15.0 cm. for the initial two-day period. The range in growth for each subsequent period was not so great. Analysis

EXPLANATION OF PLATE I

Evaporation from white porous cup atmometers at four levels in corn grown at the Agronomy Farm (dryland) during the two-month period July and August, 1941, Manhattan, Kansas. Plotted as total cubic centimeters evaporated for six-day intervals.

PLATE I


-Above tassel
-Tassel level
-Ear level
-Ground level
Cubic centimeters
600
500
400
300
200
100
0
6
12
18
24
30
36
42
48
54
60
Days after June 30

EXPLANATION OF PLATE II

Evaporation from white porous cup atmometers at four levels in corn grown at the Soil Conservation Service Nursery (irrigated) during the two-month period July and August, 1941, Manhattan, Kansas. Plotted as total cubic centimeters evaporated for six-day intervals.

PLATE II


—Above tassel
—Tassel level
—Ear level
—Ground level
600
500
400
300
200
100
0
Cubic centimeters
6
12
18
24
30
36
42
48
54
60
Days after June 30

of variance showed a highly significant difference between lines in their manner of silk growth. The difference between groups based on the group means was not significant. The highly significant group x period interaction, however, suggests a shift in the growth rate of silks of the two groups relative to time of measurement. A graphical representation of the data, shown in PLATE III bears out this fact. The growth rate of silks of the material susceptible to leaf firing exceeded that of the resistant material for the first four days and then fell below that of the resistant material for the next four days. While there was a range of from six to ten days in the length of time inbred lines continued to put forth new silk growth, the average length of time for each group was ten days. Because sufficient silks of the inbred lines were not available under dryland conditions, data were obtained only on the material grown under irrigation.

Table 6. Persistence of silk growth of six inbred lines differing in resistance to leaf firing grown at the Soil Conservation Service Nursery (irrigated), Manhattan, Kansas, 1941.

Line	Leaf firing class	Growth (cm.) by two-day intervals					
		2	4	6	8	10	12
K 167	R	10.7	6.3	4.7	1.7	.0	.0
K 201A	R	9.0	4.7	3.3	2.7	0.7	.0
Ind. 33-11	R	8.0	3.7	1.7	.0	.0	.0
Mean		9.2	4.9	3.2	1.4	0.2	.0
K 131	S	15.0	4.5	2.0	.0	.0	.0
K 151	S	12.5	6.5	1.5	.0	.0	.0
K 214	S	10.0	5.0	3.7	1.7	0.3	.0
Mean		12.1	5.3	2.6	0.7	0.1	0.0

Table 7. Showing analysis of variance of data in Table 6.

Source of variation	D/F	Sums of squares	Mean square	F value
Groups (R vs S)	1	9.33	9.33	0.70
Periods	2	486.79	243.40	18.32*
Groups x period	2	26.55	13.28	8.30**
Lines within groups	4	47.67	11.92	7.45**
Pooled lines x period	8	38.33	4.79	2.99*
Error	30	48.00	1.60	
Total	47	656.67		

* Significant
** Highly significant

Data on persistence of silk growth of the single crosses are given in Table 8 and the analysis of variance in Table 9. The data are grouped as R x R, R x S, and S x S according to the resistance to leaf firing of the parental lines. 2/ A considerable amount of variation occurs in the amount of growth of single crosses within groups. By studying the group means for each period, however, a fair estimate of the group reaction is obtained.

Under irrigation the silk growth was practically the same for all three groups for the first two-day period. Subsequent measurements, with the exception of the ten-day period, showed the R x R group to have more growth than the S x S group, with the R x S group taking a somewhat intermediate position. When grown under dryland conditions the S x S group had a silk growth of 16.2 cm. at two days compared to 11.0 cm. for the R x R group. After this initial spurt the R x R group exceeded it in amount of growth for

---

2/ R x R = Resistant x resistant
R x S = Resistant x susceptible
S x S = Susceptible x susceptible

EXPLANATION OF PLATE III

Persistence of silk growth of six inbred lines differing in resistance to leaf firing compared at the Soil Conservation Service Nursery (irrigated), Manhattan, Kansas, 1941.

PLATE III

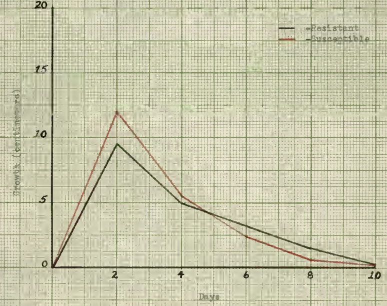

20
15
10
5
0
Growth (centimeters)
2
4
6
8
10
Days
—— -Resistant
—— -Susceptible

Table 8. Persistence of silk growth of the 15 single crosses among six inbred lines differing in resistance to leaf firing compared at the Agronomy Farm (dryland) and the Soil Conservation Nursery (irrigated), Manhattan, Kansas, 1941.

Single cross	Leaf firing class	Growth (cm.) by two-day intervals													
		2		4		6		8		10		12		14	
		I[1]	D	I	D	I	D	I	D	I	D	I	D	I	D
K 167 x Ind. 38-11	R x R	13.7	9.7	8.3	4.0	6.0	5.0	3.0	3.3	0.0	0.7	0.0	0.3	0	0
K 201A x Ind. 38-11	R x R	11.7	9.0	5.0	3.7	4.3	4.0	2.0	1.3	0.3	1.3	0.3	0.0	0	0
K 167 x K 201A	R x R	12.7	14.3	7.3	5.0	6.3	3.3	6.0	4.3	2.3	2.0	1.3	0.7	0	0
Mean		12.7	11.0	6.9	4.2	5.6	4.1	3.7	3.0	1.0	1.3	0.5	0.3	0	0
K 131 x K 167	R x S	13.3	17.6	6.7	4.7	2.3	3.7	2.3	2.0	1.0	0.0	0.3	0.0	0	0
K 131 x K 201A	R x S	15.0	17.0	6.0	6.0	6.0	6.0	5.0	3.0	1.0	1.3	1.0	1.0	0	0
K 131 x Ind. 38-11	R x S	14.3	15.3	4.7	4.3	3.3	5.3	2.3	2.0	0.7	0.7	0.3	0.3	0	0
K 151 x K 167	R x S	11.0	13.0	3.0	4.3	4.3	4.7	2.7	2.7	1.7	1.0	1.0	0.7	0	0
K 151 x K 201A	R x S	8.7	12.3	4.7	5.3	2.7	4.7	5.3	1.7	1.0	1.3	1.0	0.0	0	0
K 151 x Ind. 38-11	R x S	7.7	6.7	3.7	2.3	2.7	3.0	2.0	1.7	1.0	0.0	0.3	0.0	0	0
K 167 x K 214	R x S	13.3	11.0	5.7	3.7	3.7	3.3	4.0	2.0	0.3	0.7	0.0	0.0	0	0
K 201A x K 214	R x S	16.3	12.0	6.7	4.0	6.3	3.3	5.0	1.7	2.0	1.0	0.7	0.0	0	0
K 214 x Ind. 38-11	R x S	11.3	15.0	7.7	3.3	5.0	4.0	4.0	1.3	1.3	1.7	0.3	0.7	0	0
Mean		12.1	13.3	5.4	4.3	3.9	4.2	3.3	2.0	1.1	0.9	0.5	0.3	0	0
K 131 x K 151	S x S	12.0	12.3	4.0	3.3	2.7	3.3	2.7	1.0	1.3	0.7	0.3	0.0	0	0
K 131 x K 214	S x S	17.3	18.3	4.3	3.7	2.3	4.0	3.0	1.3	0.7	1.0	0.0	0.0	0	0
K 151 x K 214	S x S	8.3	18.0	7.3	3.7	6.7	4.3	3.3	1.0	2.7	1.3	0.7	0.3	0	0
Mean		12.6	16.2	5.2	3.6	3.9	3.9	3.0	1.1	1.6	1.0	0.3	0.1	0	0
Mean of all crosses		12.3	13.4	5.7	4.1	4.2	4.1	3.3	2.0	1.2	1.0	0.5	0.3	0	0

[1] I = Irrigated D = Dryland

Table 9. Showing analysis of variance of data in Table 8.

Source of variation	D/F	Sums of squares	Mean square	F value
Groups (RxR, RxS, & SxS)	2	6.33	3.16	0.20
Periods	3	5575.28	1858.43	120.05**
Group x Period	6	92.88	15.48	6.64**
Locations	1	18.26	18.25	7.83**
Crosses within groups	12	347.73	28.98	12.44**
Interactions				
Group x location	2	30.88	15.44	6.63**
Cross x location	12	145.37	12.11	5.20**
Period x location	3	99.19	33.06	14.19**
Pooled crosses x period	36	349.60	9.71	4.18**
Error	274	638.11	2.33	
Total	351	7303.61		

** Highly Significant

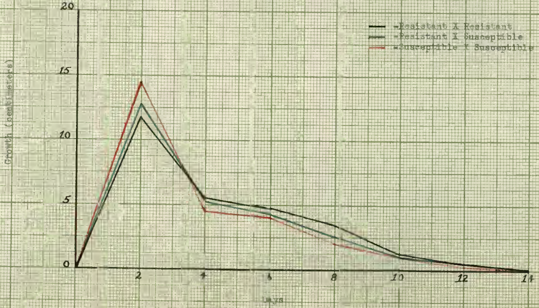
each subsequent period. Here again the R x S group in general occupied in intermediate position with respect to the amount of silk growth. It would be expected that under conditions of ample soil moisture silks would continue growth for a longer period of time than under dryland conditions. The results obtained did not bear this out. While individual crosses varied from ten to 14 days in persistence of silk growth the means of each of the three groups showed that all growth ceased at the 14-day period.

The analysis of variance showed that the grand means of the three groups were not significantly different. The highly significant group x period interaction, together with the non-significant difference between group means, indicate a change in growth rate of silks of the three groups from period to period. The growth rates of silks of the three groups of single crosses are shown graphically in PLATE IV. A striking similarity to the growth rates of their constituent inbred lines as shown in PLATE III will be noted. The fact

EXPLANATION OF PLATE IV

Average persistence of silk growth for the 15 single crosses among six inbred lines differing in resistance to leaf firing compared at the Agronomy Farm (dryland) and at the Soil Conservation Service Nursery (irrigated), Manhattan, Kansas, 1941.

PLATE IV


-Resistant X Resistant
-Resistant X Susceptible
-Susceptible X Susceptible
Growth (centimeters)
0
5
10
15
20
2
4
6
8
10
12
14
Days

that groups and crosses within groups did not react the same under different conditions of soil moisture is shown by the highly significant differences obtained between locations and for interactions involving location.

Receptivity of Silks to Pollen

Data obtained from the study of silk receptivity of six inbred lines are given in Table 10 and the analysis of variance in Table 11. Unfortunately, no silks were obtained beyond the age of ten days for the susceptible and 12 days for the resistant group so that the limit of receptivity could not be determined. Assuming that the drop in percent of seed set would have continued at the rate shown, it is doubtful whether the susceptible group would have set seed on silks more than 12 days old, while the resistant group would probably have continued to set seed on silks up to 16 or 18 days old, especially when grown under irrigation. The resistant group had considerably more seed set than the susceptible group for each corresponding silk age. The analysis of variance showed this difference between groups to be significant. There was no significant difference in the amount of seed set between the two locations. In this instance, at least, soil moisture did not influence the amount of seed set.

Data for the 15 single crosses among the six inbred lines are given in Table 12. The single crosses remained receptive to pollen for a longer period of time than did the inbred lines. All three groups reached the limit of receptivity at 16 days under dryland conditions. The drought became so acute at this time that all material became badly fired within a period of a few days which prevented the expression of any differential length of silk receptivity that might otherwise have occurred between groups. Under irrigation the limit of receptivity was reached at 20 days for the R x S and S x S groups.

Table 10. Receptivity of silks to pollen of six inbred lines differing in resistance to leaf firing compared at the Agronomy Farm (dryland) and at the Soil Conservation Service Nursery (irrigated), Manhattan, Kansas, 1941.

Leaf firing class	Location	Percent of seed set when silks were--days old						
		2	4	6	8	10	12	14
Resistant	Irrigated	80.0	65.7	49.4	35.6	21.2	11.7	-
	Dryland	98.0	60.8	67.1	35.0	12.5	6.2	-
	Mean	89.0	63.2	58.2	35.3	13.7	9.0	-
Susceptible	Irrigated	66.7	48.0	16.7	5.6	0.6	-	-
	Dryland	87.5	49.1	10.0	6.7	1.4	-	-
	Mean	77.1	48.6	13.4	6.2	1.0	-	-

Table 11. Showing analysis of variance of data in Table 10.

Source of variation	D/F	Sums of squares	Mean square	F value
Groups (R vs S)	1	25.70	25.70	12.60*
Dates (age)	4	142.39	35.60	17.45**
Group x date	4	8.15	2.04	
Location	1	0.53	0.53	0.95
Interactions				
Group x location	1	0.00		
Date (age) x location	4	4.08	1.02	1.82
Error	4	2.23	0.56	
Total	19	183.08		

* Significant ** Highly significant

Since no silks of the R x R groups were obtained beyond 14 days old, the limit of receptivity for this group could not be determined. Had silks been available, seed set would probably have been obtained up to 22 days or more. Under both dryland and irrigated conditions the R x R group showed a higher percent of seed set for each silk age than did the other two groups. As shown by the analysis of variance in Table 13, the differences observed between groups and between locations in the amount of seed set were statistically significant. The decline in seed set with silk age was gradual, with the highest set on silks that were two to four days old when pollinated. With the exception of the two-day old silks the seed set was much higher at each subsequent period for the R x R group than for the S x S group. The R x S group tended to be intermediate in amount of seed set at corresponding periods.

When the data on persistence of silk growth and receptivity of silks to pollen were plotted graphically, a striking similarity was observed between their respective trends. A graphical expression of the trends of the inbred lines is shown in PLATE V. This represents only material grown under irrigation since silk growth data were not obtained for the inbreds under dryland conditions. A graphical expression of the single cross data is shown in PLATE VI. These data represent the average of results obtained under dryland and irrigated conditions.

Correlation coefficients were obtained for both groups of data. A significant correlation coefficient of 0.7938 was obtained for the inbred lines and a highly significant correlation coefficient of 0.8834 for the single crosses between the amount of silk growth and percent of seed set for corresponding periods. The results indicate that most seed is set for the periods during which most new silk growth occurs. As the amount of silk growth tapered off the amount of seed set diminished accordingly.

Table 12. Receptivity of silks to pollen of the 15 single crosses among six inbred lines differing in resistance to leaf firing compared at the Agronomy Farm (dryland) and at the Soil Conservation Nursery (irrigated) Manhattan, Kansas, 1941.

Leaf firing class	Location	Percent of seed set when silks were days old										
		2	4	6	8	10	12	14	16	18	20	22
R x R	Irrigated	92.5	91.0	82.0	72.0	69.0	53.0	32.0	-	-	-	-
	Dryland	77.1	77.9	64.0	42.9	35.2	32.4	12.1	4.3	0.0	0.0	0
	Mean	84.8	84.4	73.0	57.4	52.1	42.7	22.0	-	-	-	-
R x S	Irrigated	93.1	82.5	73.1	62.0	52.4	36.2	24.7	13.4	6.3	2.1	0
	Dryland	40.0	43.0	39.7	34.8	22.5	9.8	7.1	1.1	0.0	0.0	0
	Mean	66.6	62.8	56.4	48.4	37.4	23.0	15.9	7.2	3.2	1.0	0
S x S	Irrigated	92.5	81.9	62.3	64.0	39.0	17.2	10.0	7.7	5.0	1.2	0
	Dryland	80.0	46.0	39.3	34.0	11.7	5.7	1.7	0.9	0.6	0.0	0
	Mean	86.2	64.0	50.8	49.0	25.4	11.4	5.8	4.3	2.8	0.6	0

Table 13. Showing analysis of variance of data in Table 12.

Source of variation	D/F	Sums of squares	Mean square	F value
Groups (RxR, RxS, SxS)	2	27.16	13.58	16.36**
Dates (age)	7	280.04	40.00	48.19**
Group x date	14	11.62	0.83	
Location	1	67.76	67.76	127.85**
Interactions				
Group x location	2	2.41	1.20	2.26
Date (age) x location	7	4.21	0.60	1.13
Error	14	7.40	0.53	
Total	47	400.60		

** Highly significant

EXPLANATION OF PLATE V

Silk growth and seed set for two-day intervals after initial emergence of silks of six inbred lines grouped as resistant or susceptible to leaf firing compared at the Soil Conservation Service Nursery (irrigated), Manhattan, Kansas, 1941.

Fig. 1 Silk growth

Fig. 2 Seed set

PLATE V

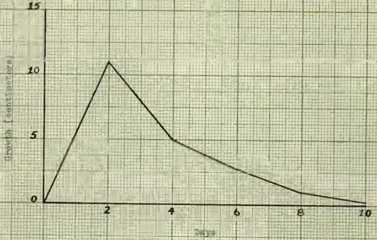


Fig. 1

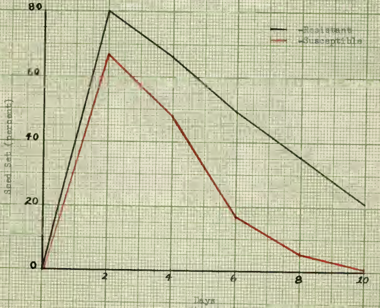


Fig. 2

EXPLANATION OF PLATE VI

Silk growth and seed set for two-day intervals after initial emergence of silks of 18 single crosses among six inbred lines differing in resistance to leaf firing. Average results of comparison made at the Agronomy Farm (dryland) and at the Soil Conservation Service Nursery (irrigated), Manhattan, Kansas, 1941.

Fig. 1 Silk growth

Fig. 2 Seed set

Plate VI

Fig. 1

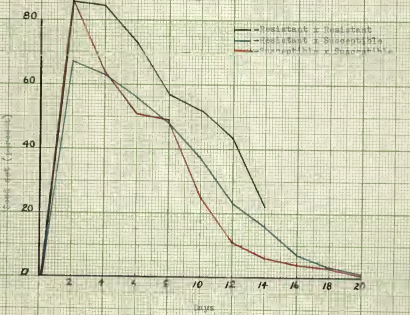


Fig. 2

Mature Length of Silks

By bagging all shoots before the silks had emerged it was possible to keep a number of silks of each kind of corn covered until they had completed their normal growth. At this time five silks of each inbred line and single cross were measured. The results and analyses of variance are given in Tables 14 to 17 inclusive.

The average length of all silks measured was greater for material grown under irrigation than for that grown under dryland. The resistant inbred lines showed more growth than the susceptible group under dryland conditions. For both groups, the average total growth was practically equal under irrigation. Analysis of variance showed the difference between groups was not significant. However, highly significant differences were obtained between silk lengths attained under dryland and irrigated conditions and also between lines within groups. The total length of silks of the inbreds ranged from 7.6 to 21.6 cm under dryland conditions and from 9.6 to 22.4 cm under irrigation.

The analysis of variance of the single cross data showed highly significant differences between groups, crosses within groups, locations, and also the group x location interaction. Examination of the group means shows the S x S group to have greater mature silk length than the R x R group at both locations. The silk lengths range from 9.2 to 26.8 cm under dryland conditions and from 14.8 to 27.[illegible] cm under irrigation. It is interesting that in all cases except two the mature silk length was greater where the material was grown under conditions of ample soil moisture. The two exceptions were K167 x K201A and K167 x Ind. 38-11. These two crosses showed about the same total length at both locations; in fact, the balance was in favor of the dry-

Table 14. Mature silk length of six inbred lines, differing in resistance to leaf firing, compared at the Agronomy Farm (dryland) and at the Soil Conservation Service Nursery (irrigated), Manhattan, Kansas, 1941.

Line	Leaf firing class	Average length (cm) when grown under		
		Dryland	Irrigation	Mean
K 201A	R	7.6	9.6	8.6
K 187	R	21.6	22.4	22.0
Ind. 38-11	R	10.4	12.0	11.2
Mean		13.2	14.7	14.0
K 131	S	15.6	17.3	16.4
K 151	S	7.8	12.0	9.9
K 124	S	11.2	13.6	12.4
Mean		11.5	14.3	12.9

Table 15. Showing analysis of variance of data in Table 14.

Source of variation	D/F	Sums of Squares	Mean Square	F Value
Groups (R vs S)	1	16.01	16.01	3.60
Lines within groups	4	1240.88	310.22	69.71**
Location	1	66.15	66.15	14.86**
Interactions				
Lines x location	4	16.77	4.19	0.94
Group x location	1	6.02	6.02	1.35
Error	48	213.73	4.45	
Total	59	1559.58		

** Highly significant

Table 16. Mature silk length of 15 single crosses among six inbred lines differing in resistance to leaf firing compared at the Agronomy Farm (dryland) and the Soil Conservation Service Nursery, (irrigated), Manhattan, Kansas, 1941.

Pedigree	Leaf firing class	Average length (cm) when grown under: Dryland	Irrigation	Mean
K 167 x K 201A	R x R	22.4	22.2	22.3
K 167 x Ind. 38-11	R x R	15.6	15.2	15.4
K 201A x Ind. 38-11	R x R	10.8	18.0	14.4
Mean		16.3	18.5	17.4
K 131 x K 167	R x S	16.8	27.6	22.2
K 131 x K 201A	R x S	26.8	27.6	27.2
K 131 x Ind. 38-11	R.x S	21.6	25.6	23.6
K 151 x K 167	R x S	16.8	21.6	19.2
K 151 x K 201A	R x S	14.4	17.6	16.0
K 151 x Ind. 38-11	R x S	9.2	14.8	12.0
K 214 x K 167	R x S	11.2	24.4	17.8
K 201A x K 214	R x S	12.4	22.0	17.2
K 214 x Ind. 38-11	R x S	13.6	21.2	17.4
Mean		15.9	22.5	19.2
K 131 x K 151	S x S	17.6	20.0	18.8
K 131 x K 214	S x S	22.8	24.4	23.6
K 151 x K 214	S x S	16.0	22.3	19.4
Mean		18.8	22.4	20.6

Table 17. Showing analysis of variance of data in Table 16.

Source of variation	D/F	Sums of squares	Mean square	F value
Groups (RxR, RxS, SxS)	2	158.17	79.08	8.94**
Crosses within groups	12	2301.40	191.78	21.67**
Location	1	988.16	988.16	111.66**
Interactions				
Group x Location	2	132.05	66.02	7.46**
Cross x Location	12	27.48	2.29	0.26**
Error	120	1062.24	8.85	
Total	149	4669.50		

** Highly significant

land and location. The average increase in total length for the material grown under irrigation over that grown under dryland conditions was 2.1 cm for the R x R group, 3.6 cm for the S x S group, and 6.6 cm for the R x S group.

The average length of the intermediate group showed a shift in relation to the other two groups between the two locations. This resulted in a highly significant group x location interaction. When the material was grown under dryland conditions the R x S group mean approached that of the R x R group, while under irrigation it equalled and even slightly exceeded the S x S group mean.

Differential Fertilizing Ability of Pollen

It has been observed that crosses made in the breeding nursery often result in poorly pollinated ears when certain lines are used as the pollen parent. The fact that this is known to occur even when optimum conditions prevail during the pollination period suggests the possibility that the fertilizing ability of pollen of inbred lines may differ considerably. Data obtained from a study of differential fertilizing ability of 25 inbred lines are shown in Table 18. The inbred lines were grouped on the basis of their resistance to leaf firing in an effort to determine whether their drought reaction might be a criterion of the fertilizing ability of their pollen.

Analysis of variance of these data is given in Table 19. There was a highly significant difference between lines in the ability of their pollen to effect fertilization when placed on silks of the single cross, W79x38-11. The amount of seed set by individual lines ranged from 12.0 to 82.5 percent. The difference between groups was barely at the five percent level of significance so that it is doubtful whether the groups based on resistance to leaf firing are different. The amount of seed obtained from using pollen of two lines of

Table 18. Differential fertilizing ability of pollen of 25 inbred lines when placed on silks of the single cross, WF9 x 38-11, Soil Conservation Service Nursery (irrigated), Manhattan, Kansas, 1941.

Resistant to leaf firing		Susceptible to leaf firing	
Line	Percent seed set	Line	Percent seed set
K 8	71.0	K 5	51.0
K 10	50.0	K 14	75.0
K 17	72.5	K 20	62.0
K 18	14.0	K 26	79.0
K 55	70.0	K 61	37.0
K 130	65.0	K 131	45.0
K 148	72.5	K 151	65.0
K 153	41.0	K 214	60.0
K 167	12.0	K 249	42.5
K 201A	82.5	Iowa 349	75.0
Ind. 38-11	67.0	Ind. 66-24	89.0
Iowa 317	58.0		
U. S. 187-2	65.0		
Ind. WF9	32.0		
Mean	55.2		61.9

Table 19. Showing analysis of variance of data in Table 18.

Source of variation	D/F	Sums of squares	Mean square	F value
Groups	1	21.17	21.17	3.94
Lines	24	452.22	18.84	3.51**
Error	91	488.83	5.37	
Total	116	962.22		

** Highly significant

the resistant group (K167 and K15) was relatively low. This is no doubt the cause of the approaching significance between groups, since there was no apparent consistent advantage of the lines of one group over those of the other. The data, while obtained from only 25 lines and only five pollinations from each line, are strongly indicative of a possible cause for the varying amounts of seed set obtained between lines used as pollen parents in making cross pollinations.

Temperature and Success of Pollination

High temperatures very often occur in Kansas at the time corn is shedding pollen. It is a widely known fact that hot, dry winds during this critical flowering period cause a serious reduction in the number of well filled ears which is reflected in lower yields of grain. Data were taken on the success of pollinations made at various temperature levels on the self-pollinated ears of inbred lines. These lines were being increased in the irrigated nursery in 1940 and 1941 (Table 20). The average percent of seed set for each day

Table 20. Average success of pollination (percent of seed set) at different temperature ranges for inbred lines being increased in the irrigated breeding nursery 1940 and 1941.

	1940		1941	
Temperature range (°F.)	Number of pollinations	Average percent of seed set	Number of pollinations	Average percent of seed set
76-80	-	-	186	64.8
81-85	10	44.0	163	64.5
86-90	368	26.4	1536	65.3
91-95	263	24.5	1485	45.3
96-100	330	24.9	1442	44.1
101-105	634	7.6	297	32.0
106-110	440	8.2	-	-
Correlation coefficient		-0.9295**		-0.8852*

* Significant

** Highly significant

was correlated with the maximum temperature for that day. The percent of seed set for any temperature range was lower in 1940 than in 1941. This appears to have been due to the fact that temperatures were higher and humidity was much lower during the pollinating season of 1940. Temperatures in the irrigated nursery during the 1941 pollinating season never were above 103°F. This together with higher humidity throughout the pollinating period kept the pollen and silks from drying out rapidly with the result of a much higher seed set.

The 1940 data, which were obtained under more adverse conditions, showed a decrease in seed set as the temperature got above 90°F. and a sharp decline from about 25 percent to about eight percent as the temperature for that day got above 100°F. The 1941 results showed a similar trend in the amount of seed set with increasing temperatures, although the decrease was not nearly so rapid. A highly significant negative correlation coefficient of 0.9298 was obtained between percent of seed set and temperature in 1940, and a significant negative correlation coefficient of 0.8352 was obtained for a similar comparison in 1941.

Although no data were recorded, pollinations made between single crosses under dryland conditions in 1940 showed a wide variation in the amount of kernels set. Since only a few pollinating bags on this material had been stamped with the date of pollination, no extensive observations could be made. A few ears of both extremes were obtained, however, on which the date of pollination had been marked. Invariably those with poor seed set had been pollinated on days with the highest temperatures and those with excellent set on days with moderate temperatures.

DISCUSSION

The factors causing incomplete pollination of corn represent, perhaps, the greatest hazard in corn production in the Great Plains area. High temperatures and low humidity accompanied by "hot winds" often occur during the critical flowering period of corn. These adverse environmental conditions may blast the entire tassel, kill the pollen grains after they are shed, or dry out the silks so that conditions are unfavorable for viable pollen to germinate. A combination of these effects probably occurs, rather than any one singly. The results of these adverse conditions is a decrease in the final yield of grain by reducing the amount of seed set and also injury to the plant so that seed which does set is not able to develop normally. Brunson and Latshaw (1934) reported that when set of grain on corn plants is prevented or reduced by prevention of normal pollination, protein and nitrogen-free-extract tend to accumulate in greater than normal proportion in other organs of the plant. Their analyses indicated that pound for pound silage or fodder from a corn crop in which pollination had been prevented is higher in protein and ash content and nearly as high in energy value as from a crop with a full set of grain. The acre yield of fodder was found to be considerably less where normal pollination and grain production were prevented. Thus from the strictly feed standpoint the lack of pollination is not as disastrous as it is from the standpoint from seed production.

Two characteristics of the maize plant make successful pollination more or less of a risk under adverse conditions. First, the maize plant requires the warmest part of the season for its growth. The critical flowering period which is usually of short duration, especially so where a field is planted to a single hybrid, occurs during the time when the droughty conditions are likely to be at their most severe stage. Early or late hybrids have the advantage in different years because their flowering period escapes the most severe weather conditions and a higher percent of seed set is obtained. The second characteristic is that the staminate inflorescense is located at the highest point of the plant and is separated from the pistillate inflorescence which occurs in the leaf axils about midway up on the plant. These facts suggest that pollen, from the time the stamens emerge from the protecting glumes of the staminate spiklet until it has been carried to stigmatic hairs of a receptive silk, is at the complete mercy of the environmental conditions existing at the time which may be and quite often are very severe. Evaporation data taken during the summer of 1941 show that the evaporation increased rapidly in a corn field from the ground surface upward. Thus, the tassel is subject to more severe drying influences than any other part of the plant. Since no shade whatever is afforded the tassle, temperatures are also greater here than in the silk region where considerable shading occurs.

Although the length of time from dehiscence of a pollen grain until it is caught by a stigmatic hair of silk may not be great, desiccation of pollen probably begins as soon as the anthers have emerged from the staminate flower. The loss of moisture may be slow at this point, but upon being released into a dry sunny atmosphere and carried for some distance by wind, drying will be greatly accelerated. Furthermore, from the time it is caught by the stigmatic hairs of a receptive silk until its germination and growth into the silk, the pollen is subject to further drying. It is, therefore, possible that unless somewhat favorable conditions prevail during the time of pollen shedding the pollen grains might easily be dried out to the point that germination cannot take place before desiccation has resulted in death of the pollen grain.

Pollen desiccation is not alone responsible for poor seed setting during hot, dry periods. The silks are also an important factor. The amount of silk growth was found to be greatest during the first four days following their initial emergence from the husks. Likewise, best seed set was obtained on silks pollinated from two to four days after their initial emergence from the husks.

One of the difficulties in attempting to measure the length of time silks remain receptive to pollen arises from the nature of corn silk growth relative to the entire ear. Silks from all florets do not emerge from the tip of the husks at the same time. Those from about the central three-fourths of the ear emerge first. Within this area the emergence does not appear to be simultaneous, but rather of a progressive nature from the tip end toward the butt end of the ear. The silks from the extreme butt and tip florets are the last to emerge. While measuring the periodical growth of silks, it was observed that during the first two or three two-day intervals the growth consisted of a uniform full brush. After this time, growth of the main body of silks ceased and the only growth observed was that of a few silks in the center of the brush from the tip florets and of a few silks around the periphery of the brush from the butt florets. It was also noted at harvest that, where ears with the older silks had been pollinated, the seed set was for the most part located at the tip and butt ends of the ear. This did not necessarily mean that the silks from the tip and buttend of the ear remained receptive to pollen for a longer period of time, but rather that these florets were slower to develop. Consequently, their silks emerged somewhat later and were receptive to pollen at the time of exposure while the earlier emerging silks had reached the limit of their receptivity at this time.

The fact that under dryland conditions, the limit of silk receptivity was reached two days after growth of silks had ceased and also that the amount of seed set followed closely the amount of new growth for each period indicates that the length of time any given portion of silk remained receptive to pollen was not very great. Where soil moisture was plentiful the limit of receptivity was not reached until about six days after growth had ceased, thus moisture seems to be an important factor in lengthening the period of silk receptivity. Apparently moisture content of the silks must be quite high for pollen to germinate rapidly and successfully accomplish fertilization. The freshest portion of the silk, i.e., the portion most recently emerged from the husks no doubt affords the most optimum conditions for pollen germination, since drying will not have occurred here to the degree it will have occurred farther out on the silks.

The results obtained in the receptivity of silk studies showed that silks of lines resistant to leaf firing set more seed at corresponding silk ages and remained receptive for a longer period of time than did silks from lines susceptible to leaf firing. The resistant groups did not taper off in rate of silk growth as rapidly as did the susceptible group. This probably explains in part the fact that the resistant group set more seed at corresponding periods after the initial emergence of silks from the husks. Since growth of all material ceased at the same time, i.e., after 14 days, it does not explain the longer period of receptivity of the resistant groups.

The exact reason for the so-called drought resistant strains of corn being more resistant to leaf firing than drought susceptible strains is not known. It has been generally conceded, however, that there is something in the physiological make-up of these resistant plants which enables them to retard water loss and thus prevent burning. If the leaves of these plants are able to retard water loss, there is some reason to believe that their silks are also able to retard water loss and thus remain receptive for a longer period. Likewise, it would seem logical to assume that pollen from these plants will be relatively more resistant to desiccation and remain in a viable condition for a longer period of time.

Cases of cross or self-incompatibility of maize are unknown, with the possible exception of a case involving popcorn lines obtained from two different varieties at Manhattan, Kansas. Crosses between lines of Supergold and South American varieties can be made only when South American lines are used as pollen parent. When the reciprocal cross is attempted, no seed is set. Casual observations in the breeding nursery over a period of years have suggested the possibility of pollen of some lines being able to effect fertilization more readily than others. Differential fertilization of corn pollen due to the presence of certain genes has been reported by Emerson (1934) and Burnham (1936). These reported cases are a result of competition of pollen differing in genetic makeup and are, therefore, not cases of incompatibility but of certation. Nevertheless, it suggests the possibility that pollen of some lines may be better able to accomplish fertilization on different strains and that the causal factor is in the genetic makeup of the various lines. Jones (1920) made the statement that the greater the benefit to the resulting progeny from cross-fertilization the less effective is that pollen in accomplishing the union. He, therefore, recognized the fact that all crosses are not made with the same amount of success and that pollens differ in their ability to effect fertilization. The data presented herein clearly indicate that differential fertilizing ability exist. Since a single female parent was used in these studies only very limited evidence was obtained. It would be expected that the same pollens would vary greatly in their ability to effect fertilization with different female parents. Further studies along this line should prove very interesting. The best evidence would be obtained where crosses between a certain group of lines were made in all possible ways. While single crosses might also be expected to differ in this character, it is not so commonly observed here as it is in the inbred lines. A study of single crosses with regard to this character might also prove interesting.

Studies made during the past two years indicate that from the standpoint of the corn breeder it is practically useless to attempt making pollinations when the temperatures are exceeding the 100 degree mark, especially when accompanied by low humidity and windy weather. In selecting plants resistant to leaf firing, plants whose silks remain receptive to pollen for a longer period of time and whose pollen is more resistant to rapid desiccation are also selected. The fact that Skold (1940) found drought resistant types to have an advantage in yield over drought susceptible types in years when droughts occur is probably due in part to a greater amount of seed set by these plants as well as to their resistance to burning. Observations on drought resistant strains as reported by Jenkins and Richey (1931), Jenkins (1932), and Sayre (1932), together with the work of Heyne and Brunson (1940) showing that drought resistance is definitely inherited, indicate the possibilities that can be achieved in breeding for drought resistance. This phase of corn breeding is especially important in regions where droughts are frequently the limiting factor in corn production. Considerable progress has already been attained at the Kansas Agricultural Experiment Station in breeding for resistance to drought and continued progress in this phase of the program will no doubt be accomplished in future years.

SUMMARY AND CONCLUSIONS

Factors affecting the success of pollination in corn growing under dryland and irrigated conditions were studied during 1940 and 1941. The factors studied included persistence of silk growth, receptivity of silks to pollen, mature length of silks, differential fertilizing ability of pollen and high temperatures.

Temperatures were higher and evaporation was greater in corn growing under dryland conditions than in that growing under irrigation. The evaporation rate, measured at ground, ear, tassel, and above tassel levels showed an increase for each higher level from the ground upward. An exception occurred under dryland conditions where the evaporation at the ground level exceeded that at the ear level after the soil surface had become thoroughly dried and the lower leaves were firing badly.

Silks of material susceptible to leaf firing grew more rapidly than silks of resistant material for the first two or three days after emergence. Silk growth of the resistant material, however, did not taper off as rapidly as did that of the susceptible material so that for subsequent periods they exceeded the susceptible material in rate of growth.

The growth of silks of inbred lines ceased after eight or nine days and that for the single crosses after 14 days. Resistance to leaf firing and soil moisture appeared to have no effect in prolonging the growth period.

Silks of inbred lines resistant to leaf firing remained receptive to pollen for about 16 to 18 days, while those of susceptible lines remained receptive for about 12 days. Soil moisture apparently had no effect on the length of silk receptivity of inbred lines.

All single crosses reached the limit of silk receptivity at about 16 days under dryland conditions.

Although under irrigated conditions, silks of single crosses between lines resistant to leaf firing were not obtained beyond the 14 day age, they probably would have remained receptive for 22 days or more against 20 days for single crosses between susceptible lines.

For each silk age, more seed set was obtained on single crosses between lines resistant to leaf firing than on single crosses between susceptible lines. This was true under both dryland and irrigated conditions.

Seed set was in a direct proportion to the amount of silk growth for corresponding periods. A significant positive correlation was obtained between persistance of silk growth and amount of seed set.

Maximum seed set was obtained where silks were pollinated two to four days after initial emergence from the husks.

Mature length of silks was greatest under conditions of ample soil moisture. The length of silks of inbreds ranged from 7.6 to 21.6 centimeters under dryland conditions and from 9.6 to 22.4 centimeters under irrigation. There was no significant difference between groups based on resistance to leaf firing. Mature silk length of single crosses ranged from 9.2 to 26.8 centimeters under dryland conditions and from 14.8 to 27.6 centimeters under irrigation. Silks of material classed as susceptible to leaf firing averaged significantly greater silk length under both growing conditions.

Inbred lines differed significantly in the ability of their pollen to effect fertilization when placed on silks of the single cross, WF9 x 38-11.

Significant negative correlations were obtained between temperature and success of pollination during 1940 and 1941 for inbred lines being increased in the irrigated nursery. Individual lines differed considerably in their ability to set seed at varying temperature levels. Some lines set seed well at the highest recorded temperatures while others had a low success of pollination at comparatively optimum temperature levels.

The amount of seed set fell off slightly as the maximum temperature for the day on which the pollinations were made exceeded 85°F. The reduction in the amount of seed set was especially marked when high temperatures were accompained by extremely low humidity.

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