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DOUBLE-CROSSES OF CORN FOR DISTRIBUTION IN MINNESOTA

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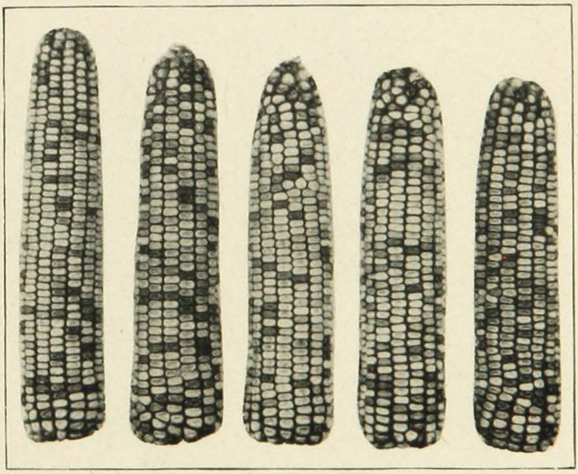


UNIVERSITY FARM, ST. PAUL

DOUBLE-CROSSES OF CORN FOR DISTRIBUTION IN MINNESOTA

H. K. HAYES, I. J. JOHNSON, and R. F. CRIM

Controlled Pollination and Selection

Present-day methods of corn breeding which are being used by many experiment stations and by some seed companies were initiated by East at the Connecticut Station and Shull at Cold Spring Harbor as early as 1905. Previous methods were on the basis of the appearance of the mother plant or ear without a knowledge of the male or pollen parents. East and Shull practiced self-pollination as a means of isolating and studying the inherited characteristics of a normal corn variety.

A kernel of corn is the result of the union of a male cell, or gamete, borne in the pollen grain with an egg cell, or female gamete, borne at the base of the silk on the ear. A pollen grain, falling on a silk, germinates and sends out a tube which grows down through the silk. This tube carries the male reproductive cell which fertilizes the egg cell and leads to the production of a kernel of corn. Pollination is brought about by the wind. Each normal tassel produces about a tablespoonful of pollen which resembles yellow dust. If fully utilized this is sufficient to fertilize about 40,000 egg cells and produce that many kernels of corn. Controlled studies have shown that practically 100 per cent of cross-pollination is the rule, i.e., the silks of a plant are pollinated by pollen of some other plant or plants. Thus the seeds of an ear result, as a rule, from the fertilization of the egg cells of a plant by male reproductive cells borne in the pollen grains of many plants.

Selection in self-fertilized lines was begun in Minnesota about 1914, and has been continued since that time. At first, work was on a modest scale, but in recent years, particularly since 1925, more extensive experiments have been conducted. In 1925 the cornbelt experiment stations and the United States Department of Agriculture adopted a co-operative project on corn improvement under provisions of the Purnell Act.

Self-fertilization by controlled pollination gives an opportunity for selection in lines in which both the male and the female parentages are known. The method for controlling pollination is illustrated in Figure 1. This makes possible the isolation of lines that breed true for their inherited characters.

A very great number of recessive abnormalities appear in self-pollinated lines. These undesirable characters do not result from self-fertilization in itself but merely become manifest. These characters are present in the normal variety, but they appear relatively infrequently. This is because the normal characteristic is dominant or covers up the abnormal. The undesirable characters are bred out of the variety by the method of selection in self-fertilized lines. After several years of self-pollination, lines are obtained that are alike in hered-

Fig. 1. Controlled Self-Pollination
The pollen from the tassel bag is poured over the silk and the ear bag placed again over the ear shoot.

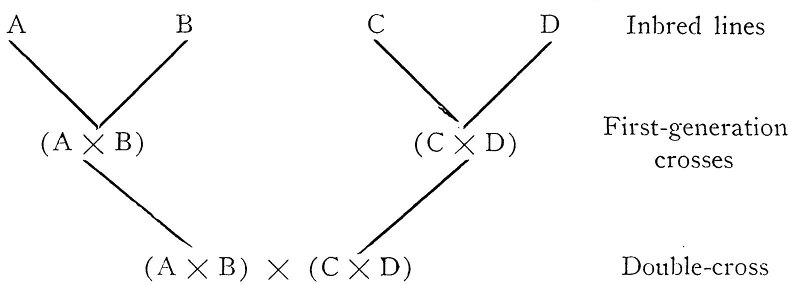
itary characters. These lines, as a rule, yield much less than normal corn. The more promising lines may be used for the production of an improved sort.

It is re'atively easy to make a cross between two varieties of corn. They may be planted in alternate rows in an isolated seed plot and all of one variety detasseled before the silks appear. Seed on the detasseled rows will be cross-pollinated.

It is very difficult to cross two pure lines and use the first-generation crossed seed to grow a commercial crop, because self-pollinated lines in themselves yield so little and because the seeds of self-pollinated lines are frequently smaller than those of normal corn. If self-pollinated lines much better in yields than those available at present could be obtained, a first-generation cross between two lines would be a practical way to produce seed corn for the commercial crop.

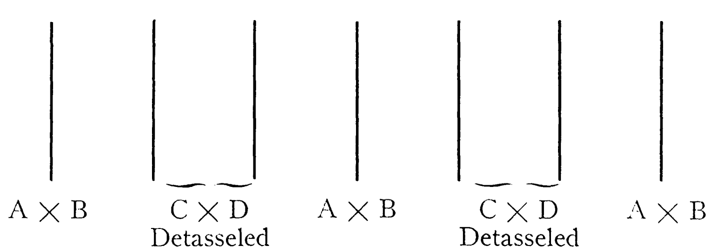
Double Cross Method of Seed Corn Production

Jones, of the Connecticut Agricultural Experiment Station, suggested the double-cross method as a means of surmounting some of the difficulties apparent in single crosses. Four self-pollinated or inbred lines are used for this method. These lines may be designated as A, B, C, and D. They have been inbred until they reproduce themselves in relatively true form year after year. The following diagram illustrates the plan:



The single crosses may be made either by controlled hand-pollination or by the use of an isolated seed plot in which two selfed lines are planted in alternate rows and one line is detasseled as soon as the tassels appear. When selfed lines are used, it may be necessary to plant more rows of the pollen-bearing parent than of the parent to be detasseled, in order to insure the production of sufficient pollen for cross-pollination.

The double-crossed seed may be produced by planting the single crosses in a seed plot and detasseling all of one cross before the silks appear. Two or three rows of the cross to be used as the female parent can be grown to each single row of the pollen parent. The method of crossing is illustrated in the following diagram:



Two rows of C × D are planted alternately with single rows of A × B, and plants of C × D are detasseled before the silks appear. This can be accomplished by walking through the plot every day and pulling out the tassels before any pollen is shed by grasping each tassel in turn and giving a firm, upward pull. In order to obtain the benefit of the cross, it is necessary that all commercial seed be produced by this method. If the double-cross is allowed to reproduce itself normally, no benefit is obtained and the new type will probably yield less than normal corn.

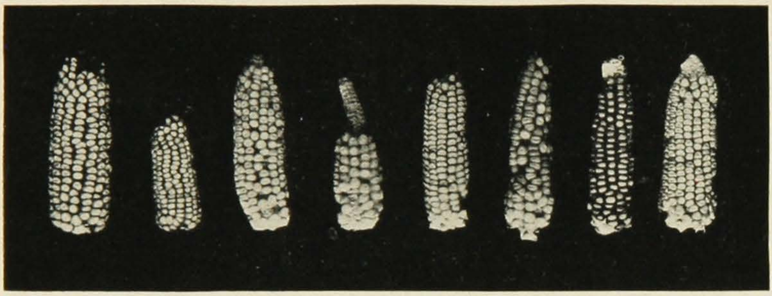


Fig. 2. Representative Ears of the Selfed Lines Used in Making First-Generation Crosses From left to right, Minn. No. 13, lines 11, 14; Rustler lines, 16, 20, 15, 19; N. W. Dent, lines 21 and 22.

Three Minnesota double-crosses have been approved for distribution. These were obtained from a combination of selfed lines of three varieties, Minnesota No. 13, Rustler, and Northwestern Dent, which are adapted to central Minnesota. The lines used are as follows:

	Selfed Line No.	Variety	Years selfed
Minnesota Double Crosses	11	Minn. No. 13	7
	14	"	13
	15	Rustler	8
	16	"	8
	19	"	10
	20	"	9
	21	N. W. Dent	9
	22	"	9

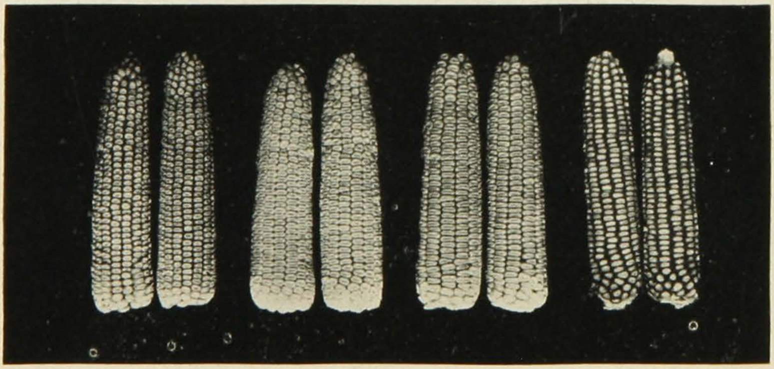


Fig. 3. First-Generation Crosses
From left to right: E, (11 × 14); I, (16 × 20); K, (15 × 19); and L, (21 × 22).

These selfed lines have been combined in the following first-generation crosses: (11 × 14) = E, (16 × 20) = I, (15 × 19) = K, and (21 × 22) = L. The selfed lines and first-generation crosses are shown in Figures 2 and 3, respectively. The double-crosses E × I, E × K, and E × L are the most promising of any double crosses tested in Minnesota for five or more years. Photographs of the selfed lines and single crosses shown in Figures 2 and 3 give a good idea of the relative productivity of each.

Yield trials of these three double crosses were made at University Farm and Morris, 1926-30, inclusive; in Goodhue County, 1926-28; in Chippewa County, 1927-30, and in Meeker County, 1928-30. These trials were made by the use of three systematically distributed plots of 3 rows per plot and from 17 to 20 hills per row. The results are given in percentage of Rustler which was grown from University Farm seed. Both Rustler and Minnesota No. 13 have been selected for several years by picking seed during Seed Corn Week, from vigorous plants in perfect stand hills, without close selection to ear type. Yield trials are summarized in Table 1.

Yield Trials of Double Crosses in Controlled Tests

Table 1

Yield, in Percentage of Rustler as 100

Variety or cross	University Farm 1926-30	Morris 1926-30	Goodhue County, 1926-28	Chippewa County, 1927-30	Meeker County, 1928-30	Grand average
Rustler	100.0	100.0	100.0	100.0	100.0	100.0
Minn. No. 13*	96.8	106.0	96.8	109.0	101.8	102.4
N. W. Dent	90.4	87.8	....	....	....	89.1
E × I	113.0	106.2	112.7	126.2	128.7	116.3
E × K	111.9	108.7	104.1	121.8	118.9	113.0
E × L†	115.5	106.2	112.8	102.4	121.9	112.0

* Not grown at University Farm, Morris 1929.
† Not grown in Chippewa county 1928-29 or in Goodhue county 1927.

The Division of Agronomy and Plant Genetics and the Agricultural Extension Service have co-operated in a test of double-crossed corn. Four hundred, 5-pound lots of seed of crosses E × I, E × K, and E × L were furnished through the county agents to the counties indicated in this report. Each farmer was requested to plant a strip in the center of his commercial field. In the fall of 1930 effort was made to check all the yields possible. This was accomplished by harvesting 50 hills of the farmer's variety and 50 from the double cross. The harvest was made in two different places in the field and from comparable plots, separated, when possible,

Comparison With Farmers' Corn

by border rows of the same variety. When the comparison was made, the total weight of the field corn was determined from full-stand, two-stalk, and single-stalk hills. The number of blank hills was counted also. Thus the yield was determined from an area of 50 hills taken as representative of the stand from the entire field. A 10-pound sample was taken to University Farm and dried to a uniform basis. The yield in bushels per acre was then computed on the basis of 14 per cent moisture. It will be noted from this description that no correction was made for differences in stand.

For convenience in studying the results, the trials have been summarized in six groups. It should be recognized that the 1930 season was abnormal because of dry weather. As the crosses mature earlier than the varieties now grown in the central and southern sections of the state, it seems probable that greater increases would be obtained in seasons less favorable than 1930 for the maturing of corn.

Group 1 consists of counties north of the Twin Cities and in the eastern sections. Nearly all of the trials were conducted in Benton, Chisago, Washington, and Sherburne Counties. The name of the cross, the number of comparisons with farmer's corn, the trials in which the crosses excelled, and the average percentage increase of the crosses over the farmer's corn are given.

Crosses	No. of trials	Trials cross excelled	Percentage increase
E × L	9	8	24.6
E × I	11	11	26.2
Total	20	19	25.5

In this group there were 20 comparisons, and the crosses gave the largest yield in 19 cases. The farmer's variety excelled in one case. The average percentage increase of the crosses over the farmer's varieties for all 20 trials was 25.5.

Group 2 consists of trials in Stevens, Ottertail, Travers, and Wilkins Counties, in the western part of the state.

Crosses	No. of trials	Trials cross excelled	Percentage increase
E × I	17	14	12.6
E × L	9	7	23.3
Total	26	21	16.3

In this group, represented by counties in the western part of the state and lying to the north of a line from the Twin Cities and the western border, the crosses averaged 16.3 per cent more shelled corn than the farmer's varieties and in 21 out of 26 trials the crosses outyielded the farmer's corn.

Group 3 consists of trials in Renville, Redwood, Lyon, Swift, Chippewa, Lincoln, Lac qui Parle, and Yellow Medicine Counties.

Crosses	No. of trials	Trials cross excelled	Percentage increase
E × I	56	42	7.4
E × K	3	3	27.5
E × L	6	5	7.5
Total	65	50	8.3

In this section were 65 trials and the crosses yielded more than the farmer's variety in 50 tests. The average increase of the crosses for the 65 comparable trials was 8.3 per cent.

Group 4 consists of counties in the east central section, Nicollet, Hennepin, Carver, Wright, and Meeker Counties.

Crosses	No. of trials	Trials cross excelled	Percentage increase
E × I	30	25	13.5
E × K	3	3	10.5
E × L	3	2	11.1
Total	36	30	13.0

For this group of counties in which there were 36 comparable trials, the crosses gave an average increase of 13 per cent over the farmer's varieties.

Group 5 consists of the southeastern Minnesota counties, Olmsted, Fillmore, Goodhue, Dakota, Winona, and Houston Counties.

Crosses	No. of trials	Trials cross excelled	Percentage increase
E × I	49	39	11.1
E × K	7	3	2.4
Total	56	2	10.0

In this group of counties the crosses excelled in yield in 42 out of 56 trials. For the 56 trials the increase was 10 per cent.

Group 6 represents the southern region where, as a rule, the latter varieties such as Golden Jewel, Silver King, and Murdock are grown. Tests were conducted in Dodge, Steele, Mower, Blue Earth, Rice, Jackson, Waseca, Brown, Martin, Faribault, Watonwan, Freeborn, Cottonwood, and Murray Counties.

Crosses	No. of trials	Trials cross excelled	Percentage increase
E × I	87	55	5.0
E × K	8	6	3.8
Average increase			4.9

In those sections in which it was expected that the crosses would prove adapted, represented by groups of counties 1 to 5, a total of 203 trials were checked. The crosses yielded more than the farmer's variety in 166 comparisons and less in 37 trials. The average increase of the crosses over the farmer's varieties for the 203 trials was 12.3 per cent.

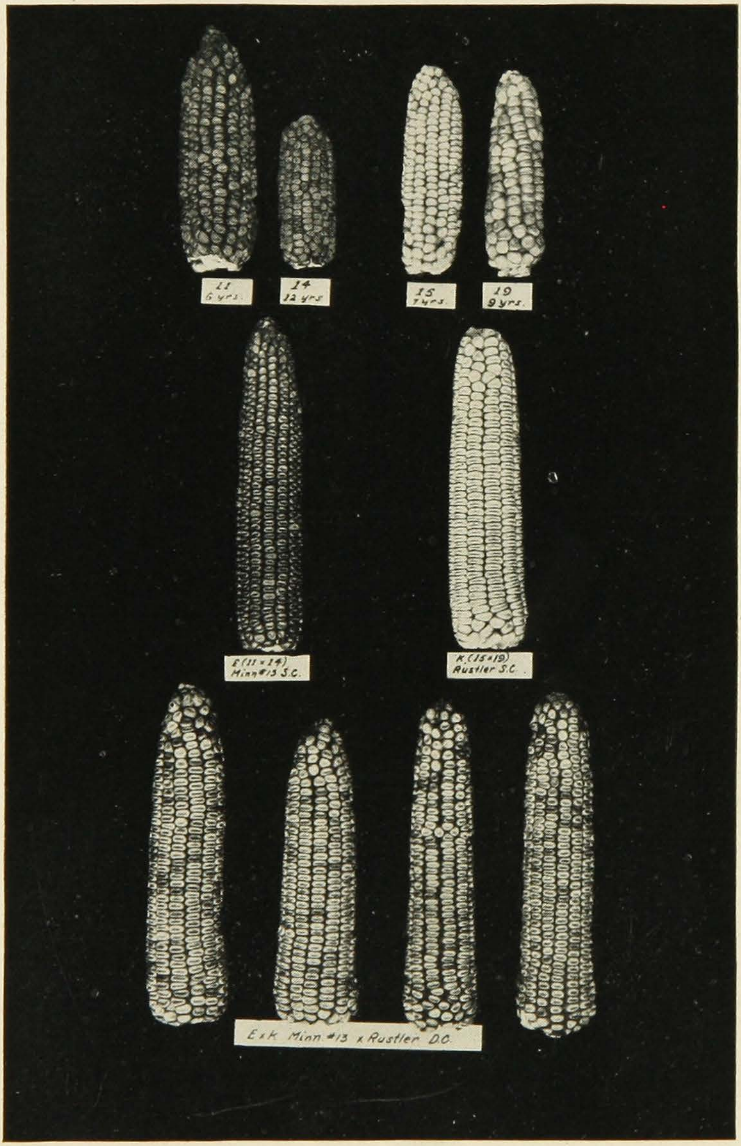


Fig. 4. Representative Ears of Selfed Lines, First Generation and Double Crosses
Above, Selfed lines, 11, 14, 15, 19
Center, First-generation crosses, E, (11 × 14) and K, (15 × 19)
Below, Double cross, E × K

In the southern section, where it might have been expected that the farmer's varieties would have excelled in yield, there were 95 trials. The crosses yielded more than the farmer's corn in 61 comparisons and less in 36 trials. For the 95 trials the crosses gave an average increase of 4.9 per cent over the farmer's corn.

Double Crosses May Be Planted Thicker Than Larger Varieties

From the study of the double crosses grown in farmers' fields, it was apparent that thicker planting of the double crosses on heavy soils in south central and southern Minnesota would give heavier yields. The double crosses produce only single ears per plant and the stalks are relatively small. To produce yields of 80 to 90 bushels per acre it is necessary to grow 4 to 5 plants per hill.

Crosses Excel in Earliness and Quality

Besides yielding more bushels of shelled corn per acre, the crosses matured several days earlier than either Minnesota No. 13 or Rustler White Dent. This was apparent by the earlier date of silking of the crosses and the lower percentage of moisture at harvest time. The increased yield of the crosses resulted chiefly from the larger number of marketable ears produced. As a rule, only a single ear was produced per stalk, but there were very few barren stalks in the crosses by comparison with the normal varieties. The crosses matured much more uniformly than the normal corn. At husking time the ears of Minnesota No. 13 and Rustler varied greatly in time of maturity and as a rule there were some soft ears with high moisture content. The crosses could be husked and cribbed much earlier than either of the standard varieties.

Seed of Double Crosses Available for 1931

Twenty-four farmers co-operated in 1930 in the production of double-crossed seed. Each of these farmers had an isolated seed plot of about one acre. The first crosses used in these crossing plots were made at University Farm by controlled hand-pollination. The cost of seed production by this method was about $1.00 per pound and enough seed for the acre seed plots was sold each co-operator at $6.00 plus cost of transportation.

Nine farmers made crosses of E × I, 13 of E × K, and 2 of E × L. The average production per acre of crossed seed of E × I was about 22 bushels; of E × K, 28 bushels; of E × L, 30 bushels. Germination and purity tests of these crosses are being made as a part of the certification service of the Minnesota Crop Improvement Association. The available seed will be listed in the seed list. Copies can be procured when available by writing to A. D. Haedecke, University Farm, St. Paul, Minn.

Kiesselbach, of Nebraska, has presented data which indicate that when each of the first crosses is grown in an isolated seed plot and allowed to pollinate itself in the normal way, as high yields can be obtained by crossing these as by using the first crosses to produce double crosses. To illustrate: Suppose first cross (11 × 14) called E, be grown in an isolated plot, and (15 × 19) or K, in another isolated plot, and each be allowed to produce seed by normal pollination. Then seed of these two varieties could be used to plant a crossing plot. The crossed seed so produced might be expected to yield as much as seed obtained by the usual method of producing a double-cross. It should be recognized, however, that these advanced-generation increases, which may be called variety E and K, would yield less seed when crossed than when the first crosses E and K were used in the seed plot. Comparative trials of double crosses E × I, E × K, and E × L, with advanced-generation crosses E × I, E × K, and E × L, obtained in each case by crossing second-generation E seed with second-generation I, K, and L seed, were made in 1930, and the results are given in Table 2.

Advanced Generaton Crosses

Table 2

Comparison of Yields of Double Crosses E × I, E × K, E × L, with Advanced-Generation E × I, E × K, E × L

	University Farm	Morris	Average	Per cent
Double Cross E × I	39.8	59.3	49.6	100
" " E × K	40.7	59.5	50.1	100
" " E × L	39.9	57.8	48.9	100
Advanced-Generation E × I	44.0	60.1	52.1	105
" " E × K	44.0	57.7	50.9	102
" " E × L	40.1	58.5	49.3	101

These results prove that advanced-generation crosses may yield as well as double crosses.

Such advanced-generation seed was available from farmers' plots in 1930. For example, if a farmer had a crossing plot of E × K, and E was the male, or tassel parent, seed of E from this plot is advanced-generation seed. If another farmer had the same cross, E × K, and used K as the pollen parent, these two farmers could together furnish seed of E and of K for a crossing plot using advanced-generation seed.

There is always a small percentage of off-pollination, even when the detasseling is performed carefully. If E is pollinated by K or I, white-capped yellow kernels result. When E is the pollen parent, such kernels may occasionally be found. These can be removed before using E as an advanced-generation parent. Similarly, if K or I was the pollen

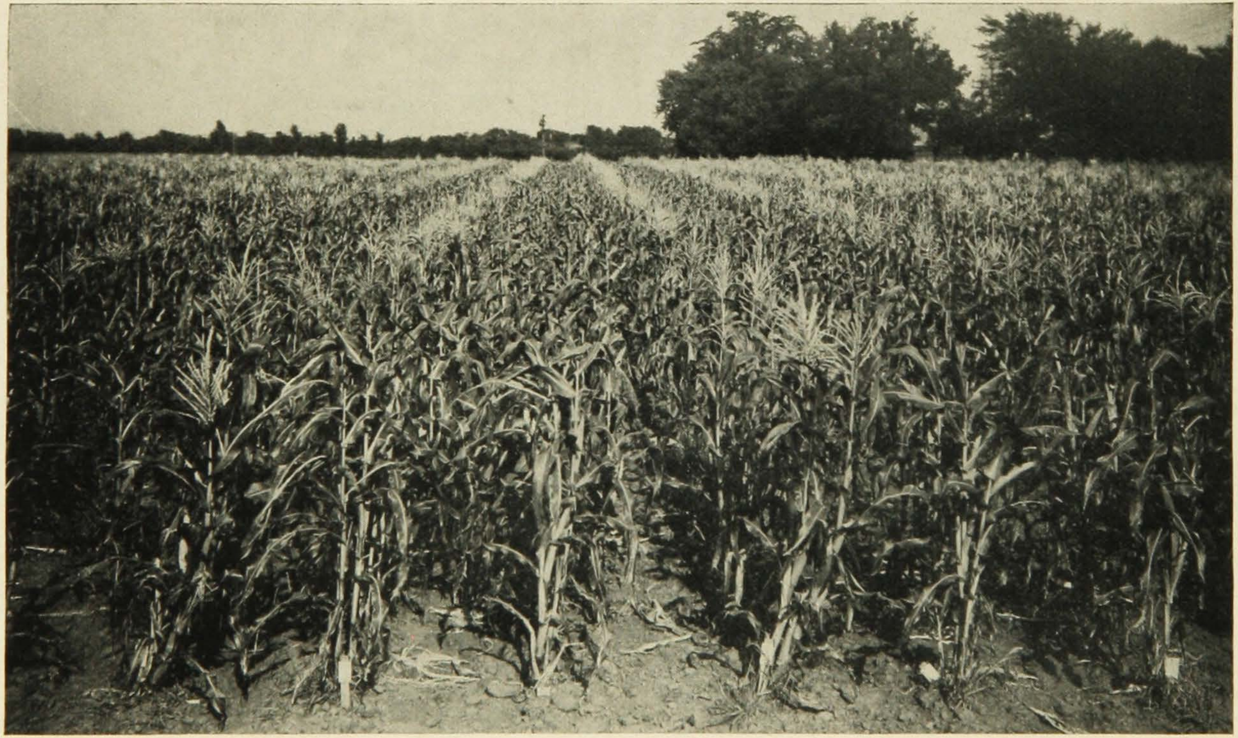


Fig. 5. Plot Shows the Method of Producing Double-Crossed Seed
Two rows of the female parent, E, were grown alternately with single rows of the male parent, I. Each plant of E was detasseled before any of its pollen shed.

parent, any light yellow, i.e., white-capped yellow, seeds may be removed with the knowledge that they are a result of pollination other than by the pollen of K or I.

The eight selfed lines and first-generation crosses were increased at University Farm and with two farmer co-operators in 1930. The amount of seed available is given here.

Seed Available of Selfed Lines and First Crosses for 1931

Selfed line or cross		Seed available
		lb.
	11	266
	14	87
	15	46
	16	646
	19	23
	20	127
	21	12
	22	26
(11 × 14)	E	231
(16 × 20)	I	477
(15 × 19)	K	76
(21 × 22)	L	113
Advanced-generation, E, I, K, L		Plenty

Seven pounds of seed of each E, I, K, and L will be retained to use as pollen parents. Forty-two pounds of the cross E, and 14 pounds of I, will be used for female parents, and three acres of each of the following crosses will be made—E × I, I × E, E × K, E × L. In order to distribute the hazard, these crosses will be made in acre plots. The male parents in these plots will be used for further production of advanced-generation seed of E, I, K, and L.

Using advanced-generations as the male parent of which sufficient seed is available, and calculating 4⅔ pounds of seed per acre for the female, the following will be available: 182, 456, 69, and 96 pounds of seed each of E, I, K, and L. This is sufficient for the following number of acres:

E ×	Advanced-Generation K	39 acres
I ×	" " E	98 "
K ×	" " E	15 "
L ×	" " E	22 "

This means that sufficient seed is available for about 190 acres of crossing plots in 1931. These must be isolated from other corn and the female line must be detasseled by removing all tassels as soon as they appear.

The cost of seed for planting an acre, which is about actual cost, is $4.00 plus postage.

If you wish to produce a crossing plot apply through your county agent, stating your facilities and the size of plot available.