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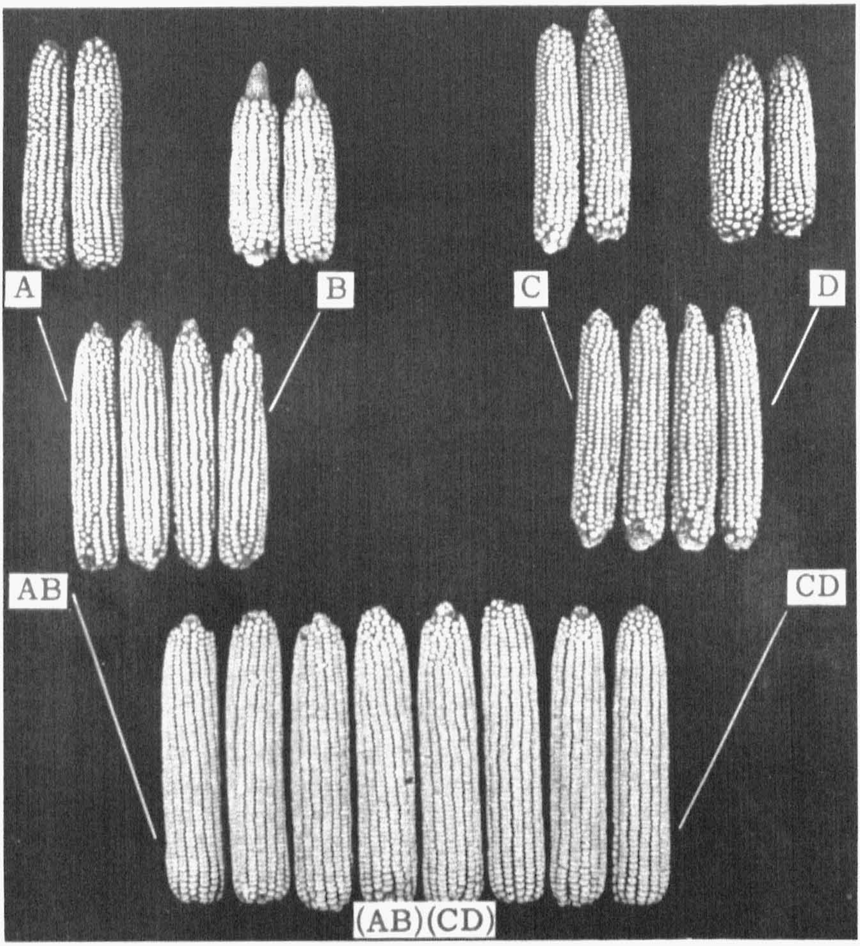
M. S. Zuber



UNIVERSITY OF MISSOURI COLLEGE OF AGRICULTURE
AGRICULTURAL EXPERIMENT STATION
J. H. LONGWELL, *Director*
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M. S. ZUBER[2]

INTRODUCTION

During the past twenty years Missouri has grown from 3.8 to 6.5 million acres of corn each year, the average being 5 million acres. At present planting rates, at least 714,286 bushels of seed are required each year to plant this acreage. Assuming 30 bushels per acre as an average yield for double-cross seed then 23,810 acres of seed plots are required to produce the hybrid seed necessary for planting Missouri's five million acres of corn.

It is estimated that approximately one-half of the double-cross seed planted in Missouri is produced within the state, with the remainder coming from surrounding states. During the past five years the Missouri Seed Improvement Association has certified an average of 2,515 acres of seed fields each year. This acreage should produce about 75,450 bushels of double-cross seed, or 10.6% of the total required to plant the Missouri corn acreage. This nucleus of certified seed has helped to maintain the high standards of quality needed for best results from the use of hybrid seed corn.

Potential growers of hybrid seed are confronted with many problems. It is the purpose of this publication to consider and discuss the procedures in the development and production of hybrid seed corn.

Economic Value

Based on a selling price of $10.00 per bushel, the hybrid seed corn required to plant 5 million acres of corn is worth $7,142,860. The production of hybrid corn seed is much more involved than the growing of feed corn. The hybrid seed producers' profits range from 5 to 25% of the retail price, depending upon production costs. Costs of production vary with the locality, season, and individual operator. Some of the extra cost items involved in producing hybrid seed include: (1) cost of single-cross planting seed; (2) labor for roguing, and detasseling; (3) sorting; (4) shelling and grading; (5) treating, bagging, and storage; (6) certification costs (if certification is requested); and (7) marketing

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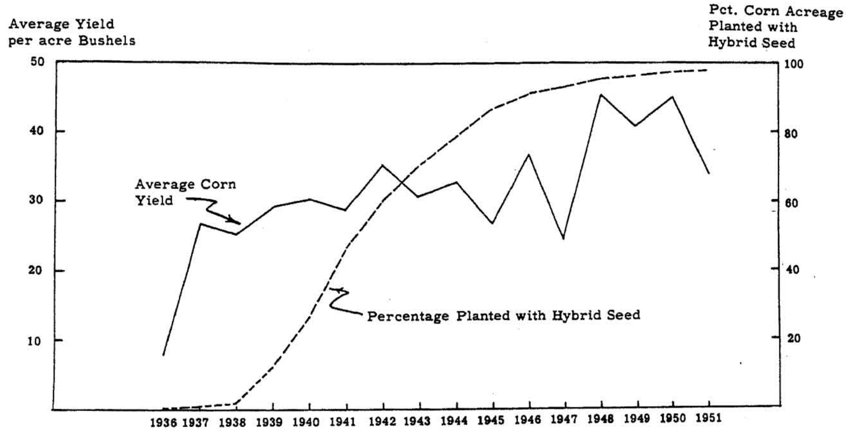


Fig. 1.—Average corn yield in bushels per acre and the percentage of the total corn acreage planted with hybrid seed in Missouri during the period 1936-1951.

costs. Hybrid seed corn production is a speciality, and a producer, who places high quality seed upon the market year after year may be justly proud of his skill and ability.

Experiment Station Corn Improvement Programs

Almost every state experiment station in the United States, where corn is an important crop, carries on corn improvement work. These organized efforts of the state experiment stations and the U. S. Department of Agriculture represents a large and concentrated effort toward the improvement of corn in the United States. Fortunately there is close cooperation among the different experiment stations with free exchange of ideas and breeding material. This enables experiment stations with small appropriations for corn research to accomplish a great deal more than would otherwise be possible.

Corn breeders of the various state experiment stations and the U. S. Department of Agriculture, have organized three regional corn conferences in order to coordinate their efforts more closely. These are the Northeastern, North Central and Southern Corn Improvement Conferences.

Most experiment stations now follow a policy of either a delayed release or non-release of new inbred lines. These policies have greatly facilitated and encouraged the exchange of new inbred lines among experiment stations. They also have kept the number of mediocre lines released to a minimum.

How New Hybrids Are Developed

Although few seed producers develop inbred lines and single crosses required to make new hybrids, it is desirable that they know something about the necessary procedures. Corn is normally a cross-pollinated crop. That is, the fine, dust-like, yellow pollen grains from the tassel of one plant are carried by wind to the silks of other plants in the field. Under normal conditions only a small percentage of the grains on a particular plant are pollinated by pollen from the same plant. In general, these "self-pollinated" grains give weaker, less productive plants. Controlled self-pollination, or "selfing," is used in the development of inbred lines. Pollen from the tassel is placed on the silks of the same plant. To exclude foreign pollen, the ear shoots, usually the uppermost, must be bagged before any silks emerge. The tassel is bagged 10 to 12 hours before pollen is collected, so that any foreign pollen which is caught on the tassel will die before the pollination is made. After pollination the tassel bag is placed over the ear and left until the ear is harvested.

When plants of an open-pollinated variety are selfed, their progeny may give rise to a number of distinct but variable lines limited only by the amount of genetic variability present in the original material. The

Fig. 2.—Corn plant with the ear shoot ready to bag.

Fig. 3.—The shoot bag on the upper shoot to protect the emerging silks from foreign pollen.

resulting inbred lines become more uniform in each subsequent generation of selfing. After five or seven generations of selfing the lines usually are very uniform. Plant variability thereafter is due mainly to differences caused by environmental factors.

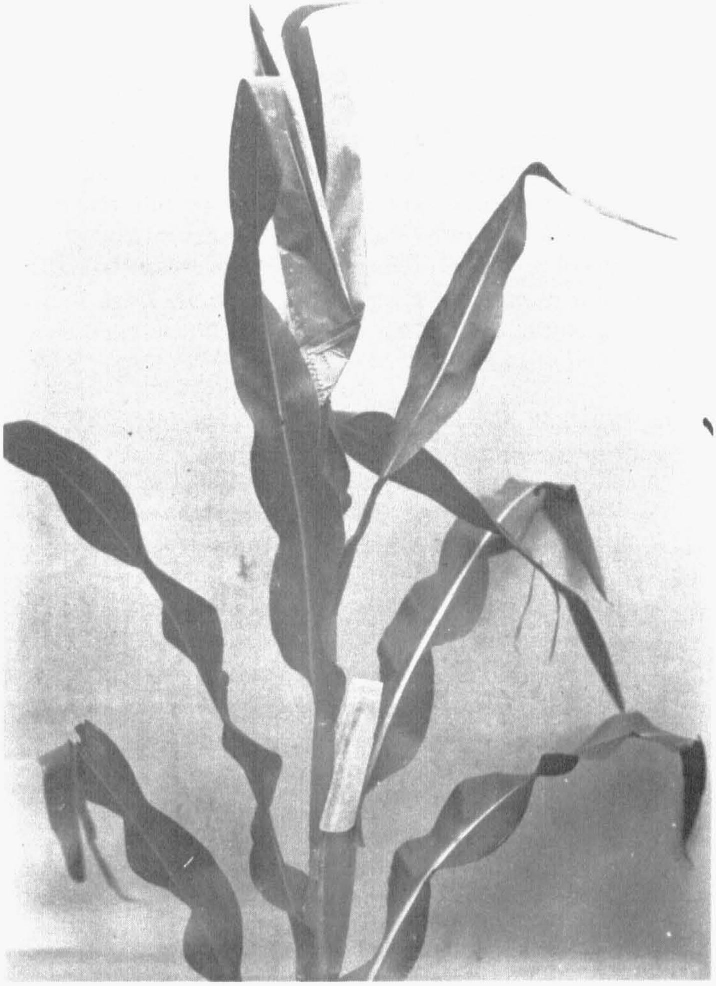


Fig. 4.—Shoot and tassel bags in place. The tassel bag protects the tassel from any stray pollen and also collects the pollen shed by the enclosed tassel.

Many undesirable characteristics hidden by the continuous crossing in the open-pollinated variety make their appearance as selfing proceeds. Examples are the inability to produce the essential green chlorophyl (which results in white seedlings or "albinism"), sterility, weak roots and stalks, and susceptibility to diseases. Lines that are uniform for these undesirable characteristics are discarded. When the selfed lines become fairly uniform and free from visible defects (usually requiring three to five generations of inbreeding), they may be tested to determine their

Fig. 5.—The pollination completed. Tassel bag has been transferred from the tassel to the developing ear, where it will stay till harvest time. The type of pollination and date usually are recorded on the bag.

ability to transmit good characteristics to their progenies. The lines in themselves are of little value to a farmer for even the best lines are weak and low in yield when compared with varieties or hybrids. They are of value only when combined to produce a hybrid better than available

Fig. 6.—First generation hybrid between two inbred lines is quite uniform for all characters and in desirable combinations is more vigorous than the average open pollinated plants.

varieties or hybrids. Thousands of lines may be produced but only a few prove to be really superior. Testing procedures are designed to identify these few outstanding inbred lines.

The first test is usually a topcross test with all of the lines crossed with a common parent, which may be an open-pollinated variety or a hybrid. The common parent may be low in yield or poor in standing ability in order to determine the lines that correct these faults and thus warrant further consideration. Usually several standard inbreds are included for purposes of comparison. The best lines identified by the initial topcross test and the most desirable of the old standard lines may then be crossed in all possible combinations, and the characteristics of each single cross determined. Once the performance of the single crosses among a number of lines is known, it is possible to predict with a fair degree of accuracy the performance of a hybrid made up of any four of the inbreds. It has been demonstrated that the characteristics of any double-cross hybrid (A x B) (C x D), will approximate the average of the four single-crosses (of the six possible among four lines) that are non-parental, namely (A x C), (A x D), (B x C) and (B x D). For example, the yield of U. S. 13, whose pedigree is (WF9 x 38-11) (L317 x Hy), will approximate the average yields of the four single crosses, WF9 x L317, WF9 x Hy, 38-11 x L317 and 38-11 x Hy.

Forty-five single crosses and 630 double crosses can be produced among ten inbred lines. The work involved in making up seed of the 630 double crosses and testing then would be prohibitive. Their performance may be estimated with reasonable accuracy, however, by testing the forty-five single crosses and using these data to predict the performance of the double crosses. A small number of double crosses selected from their predicted performance can then be made up for further testing.

The minimum time required to develop a new double-cross hybrid is about 11 years made up as follows: 5 years to develop the inbred lines, 2 years to make and test the new lines by top crosses, 2 years to make and test the single crosses, and 2 years to make and test the double-cross hybrids. After a new hybrid has been developed, it must then be compared with the standard hybrids which it is expected to replace. It is essential to conduct such comparative tests in several locations in the area where the hybrid is believed to be adapted. Because of the wide range in environmental conditions from year to year, the tests should be conducted for at least three years.

SEED PRODUCTION

The chief features of hybrid seed production are discussed below.

Foundation Seed Stocks

It is very essential that single-cross seed stocks be authentic in their genetic identity and purity. For the growers' protection, it is highly recommended that only certified single-cross seed stocks be used. Lists of certified single-cross seed producers in Missouri are available from the Missouri Agricultural Experiment Station. Many of the experiment stations now have affiliated foundation seed stock organizations. Some of these organizations are nonprofit corporations under the supervision of the Director of the experiment station formed mainly to produce single crosses involving non-released inbred lines.

A seed producer may grow his own single-cross seed stocks where they involve released inbred lines, but usually it is more desirable for the smaller producer to purchase them from reliable growers who make a business of producing this kind of seed.

Seed of single crosses is sold by the pound or on the basis of 1000 viable kernels (MVK). The second method allows for more convenient adjustment of the number of kernels if the germination is less than 100%. For example, in case of a sample with 80% germination sold on the 1000 viable kernel basis, the purchaser would receive 1250 kernels and should adjust his planting rates accordingly.

The amount of single-crossed seed required will depend on the number of plants desired per acre, the ratio of male to female rows, and the number of seeds per pound.

The number of plants desired per acre will depend upon the fertility of soil. The usual ratio for double-cross seed production is two rows of the male single cross to six rows of the female single cross. The number of seeds per pound may vary from 1000 to 2000, with an average of about 1500.

TABLE 1.—REQUIRED AMOUNTS OF SEED OF MALE AND FEMALE SINGLE CROSSES OF VARIOUS NUMBERS OF PLANTS PER ACRE. ASSUMING 1500 VIABLE SEEDS PER POUND AND A PLANTING RATIO OF TWO MALE ROWS TO SIX FEMALE ROWS.

Plants per acre	Amounts of seed required	
	Male	Female
No.	lbs.	lbs.
8,000	1-1/3	4
10,000	1-2/3	5
12,000	2	6
14,000	2-1/3	7
16,000	2-2/3	8

The amounts of seed of the male and female single crosses needed to plant one acre for double-cross production are given in Table 1.

Using figures from Table 1, a 20-acre double-crossing field having 12,000 plants per acre would require 40 pounds of seed of the male single cross and 120 pounds of seed of the female single cross.

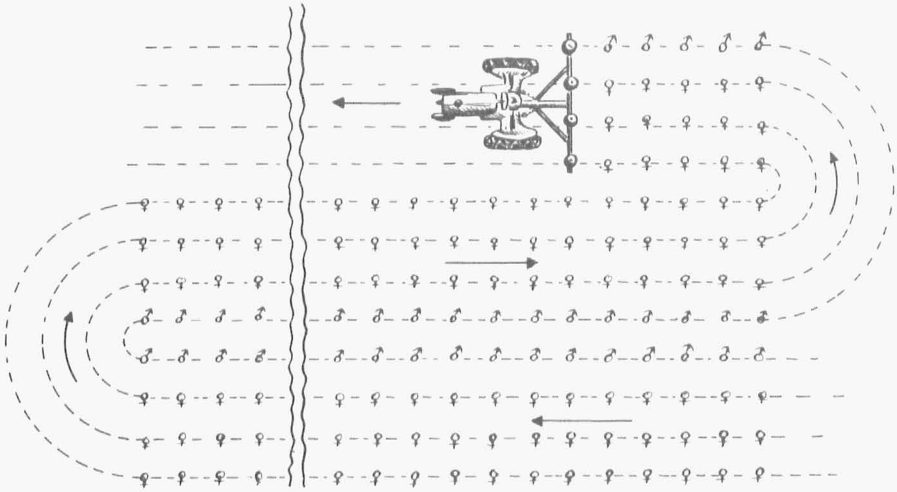


Fig. 7.—This diagram shows the method of planting a double-crossing block with a four-row planter. One outside planter box is filled with male single-cross seed and the remaining three boxes with female single-cross seed.

Fig. 8.—A double cross seed production field showing the ratio 2 male rows (with tassels) to 6 female rows (detasseled).

Cultural Practices

The cultural practices suited to general field corn production apply equally well to the production of hybrid seed corn, with the exceptions of time and depth of planting. Single-crossed seed is smaller than that of most double crosses. The seedlings from small seeds usually have less vigor than those from large seeds. For that reason planting should be delayed until the soil is thoroughly warm. Under Missouri conditions this probably would be a week or ten days later than the usual planting date for corn. Single-cross seed should not be planted as deeply as field corn. The depth of planting should be governed by soil moisture but should not be deeper than necessary for germination of the seed, or about 1½ inches. Many poor stands are the result of planting too deeply.

The use of 2,4-D chemicals in weed control is definitely recommended where conditions warrant, but certain precautions are necessary.

Planting

Under ordinary weather conditions the ratio of two rows of the male single cross to six rows of the female single cross will provide ample pollen for good seed sets. In areas where adverse weather conditions are likely to prevail during the pollination period more pollen rows may be necessary, and a ratio of two male rows to four female rows may be more satisfactory.

The use of a two to six ratio is convenient when a four-row planter is used. One of the outside planter boxes is filled with seed of the male single cross and the other three boxes with a seed of the female single cross and each round trip of planting will provide a ratio of two to six. When the two to four ratio is used the male rows can be planted with a two-row planter and the female rows with a four-row planter. If a four-row planter only is used, the planter boxes must be shifted.

Seed production of double crosses that necessitate a split planting date of the male and female rows, should be avoided if possible. Wet weather often precludes the planting of seed of male or female rows on planned separate dates.

Table 2 shows the spacing of plants within the row for different spaces between rows where 8,000 to 16,000 plants per acre are desired.

TABLE 2.—REQUIRED SPACING OF PLANTS WITHIN ROWS FOR VARIOUSLY SPACED ROWS AND PLANT POPULATIONS PER ACRE.

Plants per acre	Distance between plants within rows spaced as indicated			
	36" Rows	38" Rows	40" Rows	42" Rows
No.	inches	inches	inches	inches
8,000	21-3/4	20-1/2	19-1/2	18-2/3
10,000	17-1/3	16-1/2	15-2/3	14-3/4
12,000	14-1/2	13-3/4	13	12-1/3
14,000	12-1/3	11-3/4	11-1/4	10-2/3
16,000	11	10-1/4	9-3/4	9-1/3

Isolation

Some of the factors which may affect contamination in seed fields are: (1) distance of isolation, (2) height and number of border rows, (3) direction and velocity of the wind during the pollen shedding period, (4) quantity of pollen produced by the male single cross, (5) time of the

Fig. 9.—(A) Plant from an open pollinated variety. The individual kernels are related on the female side but may be quite unrelated on the male side, the pollen having come from numerous plants within the field. Each kernel is the result of a separate fertilization. (B) The plants grown from the seed of an open pollinated ear of corn are variable in height, size of ear, etc., but on the average retain the general type of the parent variety.

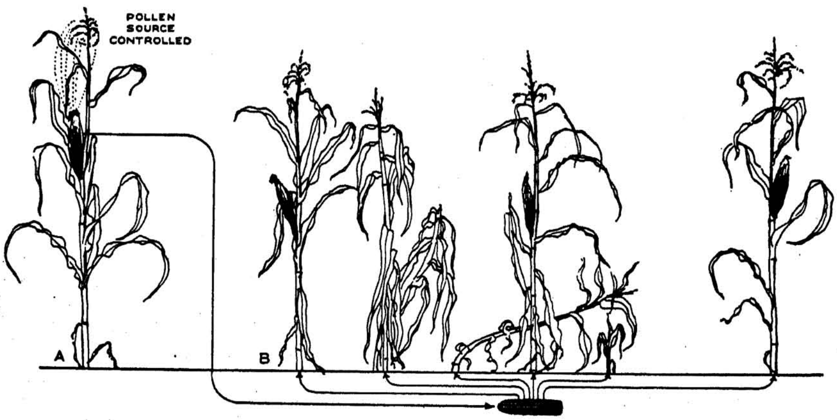


Fig. 10.—When a plant grown from open pollinated seed (A) is self-pollinated, the individual kernels are related to both the male and the female side. When seed from this ear is planted (B), segregation for plant and ear characteristics occurs. Many of the plants are undesirable; for example, 2, 3 and 5 are discarded. The plants having desirable characters; that is, 1, 4 and 6, are used for further self-pollinations. Self-pollination and selection continue until the lines have become "fixed" or true breeding. This usually requires three to seven generations.

season and time of the day of pollen shedding and, (6) weather conditions that affect shedding and viability of pollen.

The seed producer must rely upon adequate isolation and an abunance of pollen of the male parent at the proper time. Table 3 gives the isolation requirements for certification taken from the Regulations and Standards for Seed Certification, published by the Missouri Seed Improvement Association.

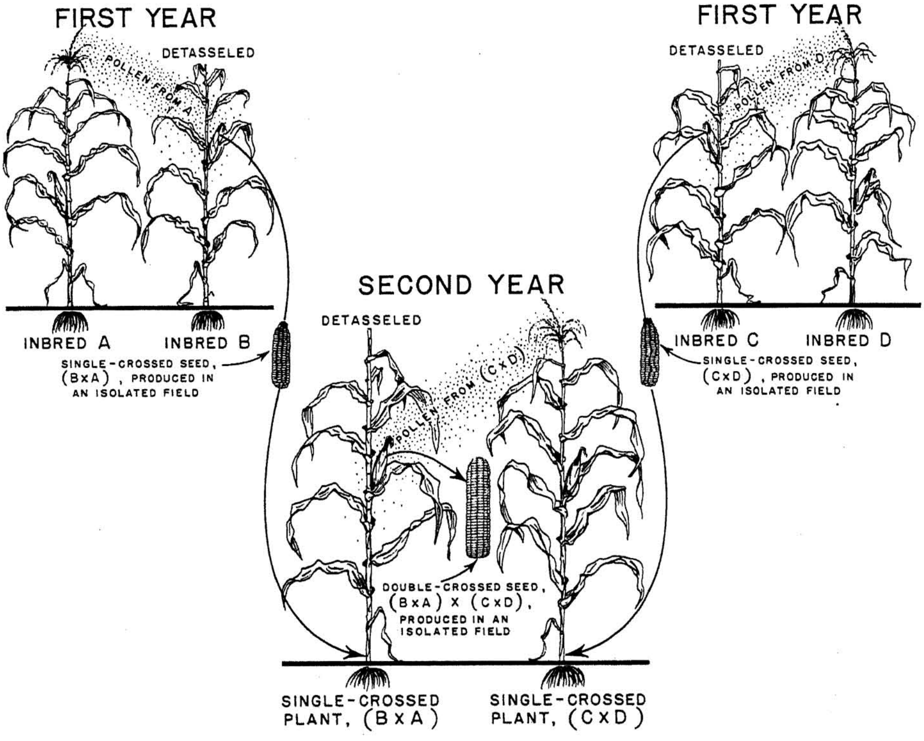


Fig. 11.—Method of producing single and double crosses. (Diagrams used by courtesy Iowa Agricultural Experiment Station.)

Roguing

A few off-type plants will occur in spite of all care and precaution taken in the production of single-cross seed. Such plants must be removed as soon as they are recognized. The field must be rogued several times in order to find and remove all of the off-type plants.

Roguing should be repeated during several stages starting when the plants are small seedlings and continuing until the ears harvested from the female rows are ready to shell. Even then all off-type plants may not be recognized and removed. If the number can be kept to a minimum the double-crossed seed will be relatively pure.

TABLE 3.—ISOLATION OF DOUBLE-CROSS SEED PRODUCTION FIELDS TO QUALIFY FOR CERTIFICATION (SWEET OR POPCORN MUST BE 80 RODS AWAY).

When the number of acres in the crossing field is								number of Then at least this border rows is required
9 or less	10-14	15-19	20-24	25-29	30-34	35-39	40 or over	
and the distance of the ear parent from other corn is at least								
ft.	ft.	ft.	ft.	ft.	ft.	ft.	ft.	
660	644	627	610	594	578	562	545	2
610	594	578	560	545	528	512	495	2
578	560	545	528	512	495	479	462	3
528	512	495	480	462	446	429	413	4
495	480	462	446	429	413	396	380	5
445	429	413	396	380	363	347	330	6
413	396	380	363	347	330	314	297	7
363	347	330	314	297	280	264	250	8
330	314	297	280	264	248	230	215	9
280	264	248	230	215	198	185	165	10
248	230	215	198	182	165	149	132	12
198	182	165	149	132	116	100	83	14
165	150	132	116	100	83	66	50*	16

*If less than 50 feet must have 24 border rows.

If time is a limiting factor effort must be concentrated in removing off-type plants from male rows before they shed pollen. Off-type plants and ears may be removed from female rows after pollination, but it is desirable to remove any off-type plants as soon as they are recognized. In case of doubt suspected off-type plants should be rogued out.

Seed fields should not be located on land that grew corn the previous year. Volunteer plants are likely to appear and may be very difficult to recognize, especially if the corn was closely related to the double-crossed seed being produced.

Detasseling

All tassels must be removed from plants of the female rows (ear parent) before they shed pollen. Failure to remove tassels from plants of the female parent before they shed pollen will result in self or sib-pollination within this parent. This will be reflected in a lowered yield of the double cross. Missouri certification requirements for detasseling are as follows:

a. A field must be rejected if, on any one inspection, more than 1% of the ear parent plants have shed pollen after the silks are showing, or
b. If the total for any three inspection dates exceeds 2%. Sucker tassels, portions of tassels or tassels on main plants will be counted as shedding pollen when 2 inches or more of the exposed tassel, or parts of tassel, has the anthers extending from the glumes.
c. All ears on rows to be detasseled which have exposed silks must be removed if, on the first detasseling, pollen is being shed from these rows.

d. Pollen parent rows—On the first detasseling date there must not be more than .1% definitely off-type and/or volunteer plants, or more than 2% doubtful plants in the pollen parent rows.
e. Ear parent (detasseled) rows—By the time of the last field inspection, there must not be more than .1% definitely off-type and/or volunteer plants, or more than 2% doubtful plants.

Detasseling is very laborious since it must be done by hand. A new producer must consider the labor supply available for detasseling before he decides upon the acreage he should grow. Tassels must be removed from the female row promptly after they emerge to avoid serious consequences later. Rainy weather may hinder the operation, but the tassels must be removed rain or shine.

The detasseling of an individual field may last from ten days to three weeks. Not all of the tassels appear at once and it usually is necessary to go over the field every day until most of the tassels have been pulled. Then the field can be gone over every other day, or every fourth day late in the pollinating season. The last trip through the field should clean out the final tassels on the female plants.

From 20 to 80 man-hours may be required to remove the tassels from an acre of corn. The time required varies with the weather conditions, number of plants per acre and the characteristics of the seed parent, whether it is tall or whether the leaves are rolled in the tassel.

Detasseling machines are available which carry laborers through the field at the proper height to pull the tassels. These machines increase the efficiency of the operation. Older workers and women may be used more satisfactorily on detasseling machines. The machine cannot be used if the corn is lodged badly, and some difficulty may also be experienced due to poor traction in wet weather. It is rather difficult to change laborers from a riding to walking job in case the machine cannot be used.

Small reductions in yield may result when leaves are removed with the tassel, depending upon the relative amount of leaf tissue removed. As might be expected, the removal of one leaf from a tall vigorous plant would not be so serious as the removal of a leaf from a small plant. Experimental data indicate a reduction of from two to three percent in grain yield from the removal of one leaf and about twice this amount when two leaves are removed.

HARVESTING

Only the seed from the detasseled rows is hybrid seed. This may be harvested either by hand or with a mechanical picker. The most desirable mechanical picker is the two-row mounted type which will harvest two rows without disturbing the adjacent ones. Machines of this type permit removing the pairs of male rows while leaving the six female rows to be

Fig. 12.—At the left is a hybrid with good standing ability, while the hybrid at the right has a high percentage of root lodging, indicating a poor root system.

harvested separately. This eliminates any chance for the mixing of ears from male and female rows. Care must be taken in adjusting the mechanical picker to avoid any unnecessary damage to the seed.

The moisture content of the kernels should be below 30% when harvesting is begun, and if the moisture content is above 20%, facilities should be available to dry it promptly. A mechanical picker will damage the seed considerably when the moisture content exceeds 30%. Many producers in Missouri allow the seed to dry in the field to a moisture content of 16 to 18% before harvesting. In this case the corn should be sufficiently mature to avoid possible damage by frost, and should be free from stored grain, insects, particularly Angoumois moth.

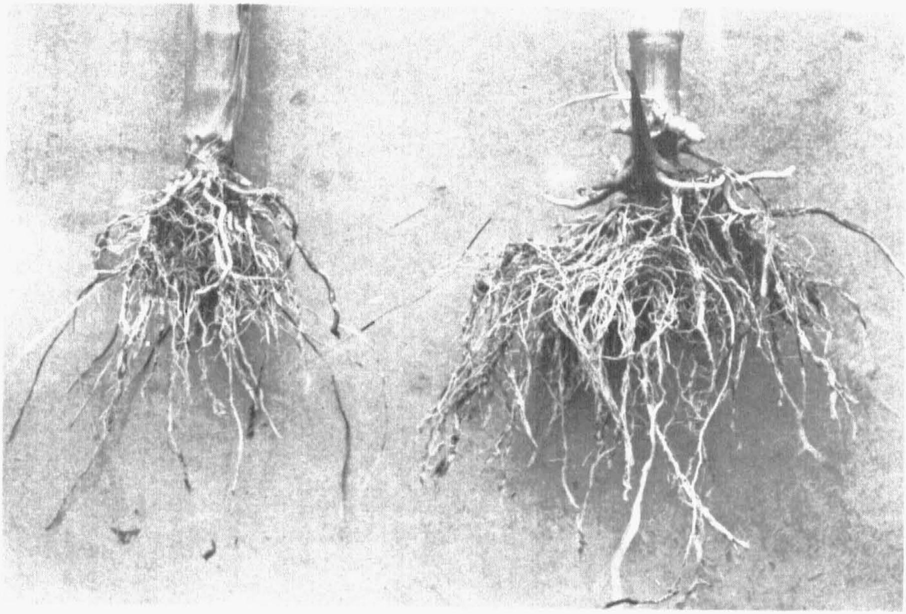


Fig. 13.—The difference between the two root systems shown here illustrates the basis for segregation of hybrid strains for root size and vigor in the early stages of inbreeding in developing new inbreds.

Sorting

As corn comes from the picker, it is very desirable to pass the ears over another set of husking rolls to remove any remaining husks or silks. After this operation the ears may be placed on a moving belt or a table for hand sorting and to permit the removal of damaged and diseased kernels from each ear. Whether an entire ear or only a portion of an ear is removed will depend upon the amount of damage to the ear and availability of the labor involved. It is much easier to remove damaged and diseased ears before shelling than to attempt to remove damaged kernels from the shelled corn.

Where corn is grown under contract, it is usually advantageous to sort the corn on the farm where it has been grown. The off-type and diseased ears then may be left for disposal by the farmer.

Drying

The most common method of drying seed corn is to force heated or unheated air through the ears which usually are piled up in a bin. The air is forced through the slotted or screened bottom of the bin and upward through the corn. The sides of the bin are air tight. The exhaust air from the top of the bin may either be diverted through another bin in the opposite direction or merely allowed to escape, depending upon the amount of moisture it is carrying when it reaches the top of the bin. Air passing through corn that is nearly dry can be used effectively to dry corn in another bin. The depth of the pile of corn will depend upon the air velocity furnished by the fan used.

The heat source may be a hot air furnace using either oil, gas or coal fuel.

The air temperature may vary from 105° to 107° Fahrenheit, but must not exceed 110°F. if injury and lower germination is to be avoided.

Drying may also be accomplished by forcing unheated air through a bin of corn. This method is safer and cheaper than the use of heated air but the volume of corn dried is decreased considerably. Several companies specialize in furinshing drying equipment and a new producer should consult such individuals before purchasing elaborate equipment.

The moisture content should be reduced to about 13 percent before the ear corn is shelled.

Shelling and Grading

Seed corn should be shelled with care and in such a manner as to result in as little injury as possible. The moisture content of the kernels and speed of the sheller both influence the amount of injury. Data from an experiment conducted at the Iowa Experiment Station indicated that there was much less damage to corn shelled with 12% moisture than with 7.6% moisture.

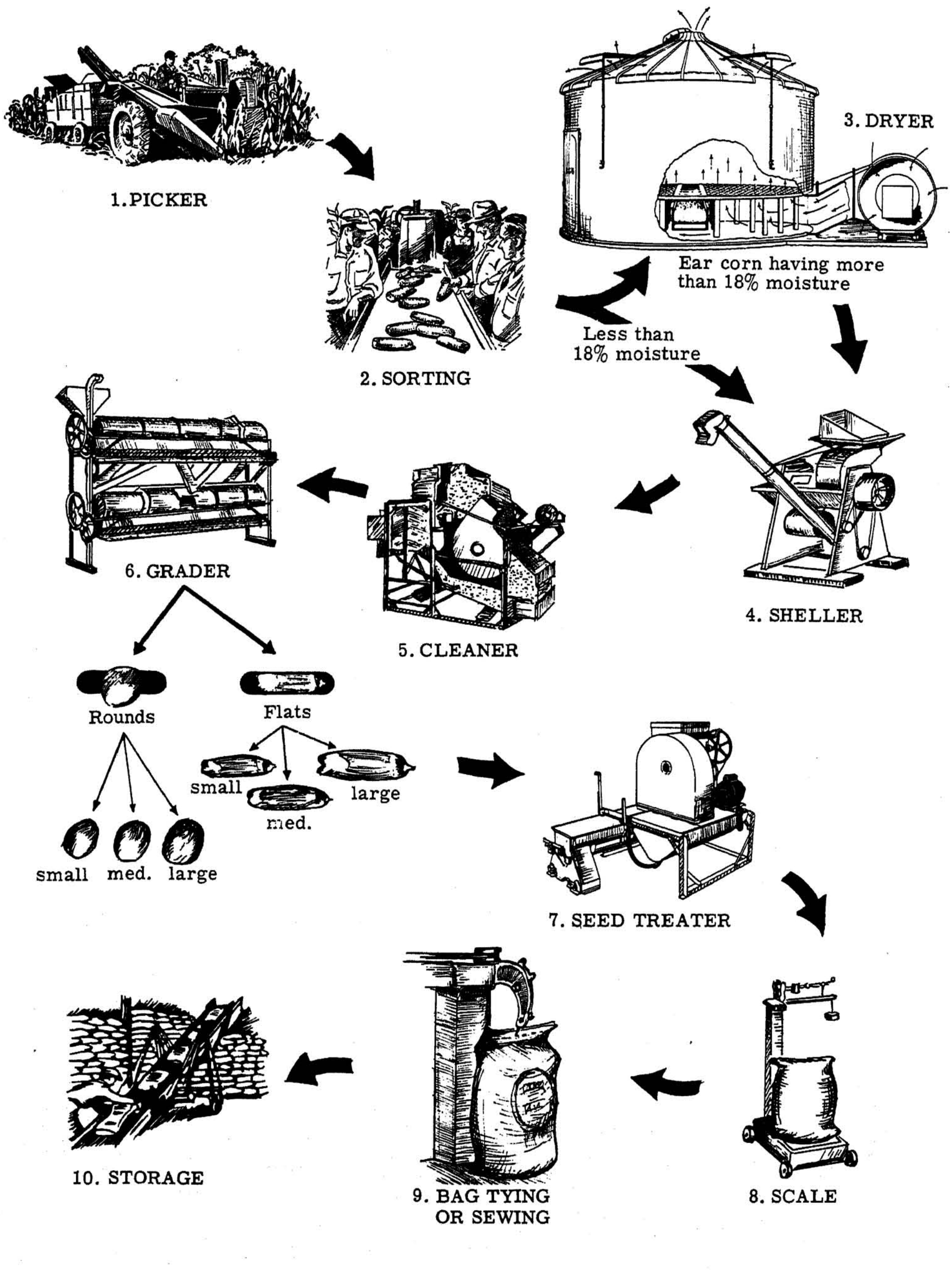
After the corn is shelled the kernels are graded for size and shape. Most seed corn is graded for the two shapes, flat and round. The flat and round kernels each are divided into small, medium and large making a total of six grades.

Grading is accomplished by first running the shelled corn over a ring grader which separates the round kernels from the flat ones. These in turn are sized by passing the corn over perforated screens.

Bagging and Storage

Seed corn is usually marketed in bushel bags containing fifty-six pounds of shelled corn, plus a small overweight to compensate for possible shrinkage. Manufacturers offer bags of the required special size made of closely woven cotton cloth. The Missouri Seed Improvement Association

HYBRID SEED CORN PROCESSING FLOW CHART



purchases large lots of bags for resale to certified growers. Usually the bag will have the name and address of the grower printed on it, and if the seed is certified in Missouri, the bag will have the seed certification emblem printed on it.

After the seed corn has been treated and bagged, it is stored until sold or moved to retail markets. The storage room should be rodent proof, cool and dry.

Seed corn carried over until the next season should be reduced to a moisture content of 6 to 10% and then stored at a temperature below 40 degrees Fahrenheit. Such temperatures help to retain viability and greatly retard insect activity.

SEED TREATMENT

Chemical seed treatments for corn have received intensive study since the introduction of organic mercuric fungicides. Experimental results with these chemicals have varied widely in different areas and seasons. Numerous patented materials have been put on the market and their use strongly advocated by the companies producing them. This has resulted in much uncertainty regarding the necessity for seed treatment and the most desirable material for treatment. In general seed treatment is most effective when the seed is planted in cold, wet soil, under conditions unfavorable for germination and seedling growth. This is particularly true if the seed has been damaged mechanically in handling. Since the weather following planting cannot be predicted with accuracy, it is advisable to plant treated seed. Damage is likely to occur to some extent with present methods of processing even with the greatest care on the part of the processor. Seed treatment will increase the number of healthy seedlings when adverse weather conditions prevail during the period of germination and emergence, and the cost of treatment is so low that seed treatment will return benefits over a period of years.

Large numbers of materials have been tested but at the present time only a few are recommended. Arasan, Phygon, and Spergon are the leading fungicides now in use and in general practice they are applied as a slurry, but they are equally effective as dusts. The slurry treatment consists of applying the material in water suspension with a special type of machine. Such machines are used by larger producers, but the costs involved make such equipment impractical for the small operator. Their chief advantage is the removal of the dust hazard to operators. The materials used are irritating to operators and care must be exercised in their handling. With proper care the dust treatments may be made effectively in a homemade treater. Plans for construction of such treaters may be obtained from county agents or from the Extension Service of the Missouri College of Agriculture.

SELECTION OF HYBRIDS

The seed producer must consider many factors before selecting a hybrid. Some of these factors are as follows: 1. Does the hybrid's area of adaptation match the area where the seed is likely to be sold? 2. Is the hybrid popular among farmers? 3. Does it have a satisfactory performance record? 4. Is the seed difficult to produce?

Some of the answers to these questions may be obtained from the agricultural experiment station and the state certifying agency. Others may be had from a small-scale production of the hybrid under consideration. It is recommended that the producer of a new hybrid or an inexperienced grower follow a policy of producing a small trial acreage, and thereby learn through practice the problems concerned. Only after he has found the hybrid that satisfies both him and his customers should he expand his production.

Recommended lists of hybrids that are eligible for certification may be secured from the Missouri Seed Improvement Association, 108 Waters Hall, Columbia, Missouri. Brief descriptions and performance records of hybrids may also be secured from the Missouri Agricultural Experiment Station's Bulletin 546, Corn Hybrids Adapted for Missouri.