Hybrid Seed Corn Production

M. S. Zuber and C. O. Grogan

It is estimated that about 700,000 bushels of seed corn are required to plant Missouri's annual corn acreage. This estimate is based on planting rates of 12,000 to 14,000 plants per acre on an average of 4.5 million acres. Assuming 30 bushels per acre as an average yield for double cross seed, then about 23,000 acres are required annually to produce the hybrid seed to plant the corn acreage in Missouri.

It is further estimated that approximately one-half of the double cross seed requirement is produced within the State, with the remainder coming from adjacent States. Missouri's certified corn acreage of about 2,500 to 3,000 acres thus constitutes only about 10 percent of the total required.

The development and production of hybrid seed corn are of much interest to students of agriculture as well as to farmers. This bulletin covers the procedures and problems associated with both enterprises.

ECONOMIC VALUE OF HYBRID CORN

The monetary value of hybrid corn to the Missouri farmer is difficult to estimate. The first comparative yields between hybrid and open-pollinated varieties gave a 15 percent average yield increase by the former. In addition, hybrid corn had more lodging resistance and dropped fewer ears than open-pollinated varieties as well as having more disease and insect resistance. Today, hybrids are even better in these features than the hybrids that replaced the open-pollinated varieties (See Table 1). The yield increase from hybrids is now nearer 20 or 25 percent than to 15 percent. The average yield increase attributed to the use of hybrid seed is shown by the comparative average yield in Figures 1 and 2. Never in the history of Missouri corn production from 1866, when yearly records were first compiled, did the average yield exceed 30 bushels per acre until hybrid seed was used, but the average yield exceeded 30 bushels in 10 of the 15 years from 1941 to 1955.

All of this increase can not be attributed to the use of hybrid seed alone since added fertilizer and improved cultural practices also played an important part. Figure 2 shows the annual average yield and percentage of total acreage planted with hybrid seed. The relative increase in average yield with increased use of hybrid seed is noteworthy.

The value of the hybrid seed corn required to plant Missouri's annual corn acreage is about 7 million dollars based on a selling price of $10.00 per bushel. The production of hybrid seed is much more involved than growing corn for feed or for the cash grain market. Some of the extra production costs include: (1) cost of foundation seed stocks; (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 costs.

### Table 1 -- Comparative Performance Records of New and Older Established Hybrids from a Mechanical Picker Test Conducted Near Maryville, Missouri, in Nodaway County in 1952.

<table>
<thead>
<tr>
<th>Variety</th>
<th>Acre Yield</th>
<th>Moisture in Grain</th>
<th>Stalk Lodged Plants</th>
<th>Picked Clean Corn</th>
<th>Pickled Corn With Shucks</th>
<th>Bu. Per Acre Remaining in Field</th>
<th>Shelled Corn Bu. Per Acre</th>
</tr>
</thead>
<tbody>
<tr>
<td>Older Established Hybrids</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>US 13</td>
<td>103.1</td>
<td>15.9</td>
<td>9.3</td>
<td>40.6</td>
<td>59.4</td>
<td>25.8</td>
<td>4.2</td>
</tr>
<tr>
<td>Mo 148</td>
<td>100.0</td>
<td>15.1</td>
<td>15.4</td>
<td>54.5</td>
<td>45.5</td>
<td>27.5</td>
<td>4.2</td>
</tr>
<tr>
<td>New Hybrids</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mo 843</td>
<td>111.1</td>
<td>18.6</td>
<td>1.6</td>
<td>25.8</td>
<td>74.2</td>
<td>5.7</td>
<td>3.1</td>
</tr>
<tr>
<td>AES 801</td>
<td>114.7</td>
<td>16.8</td>
<td>1.4</td>
<td>19.8</td>
<td>80.2</td>
<td>6.7</td>
<td>4.0</td>
</tr>
</tbody>
</table>

1 Agronomists, Field Crops Research Branch, Agricultural Research Service, U.S. Department of Agriculture; and Research Associates, Department of Field Crops, University of Missouri.

Department of Field Crops (Corn Breeding Project 85), Missouri Agricultural Experiment Station, Field Crops Research Branch, Agricultural Research Service, U.S. Department of Agriculture; cooperating.
CORN IMPROVEMENT PROGRAMS

State Experiment Stations and U.S.D.A.

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 represent 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 otherwise would 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. Geographically, these are the Northeastern, North Central, and Southern States.

The ultimate objective of these corn improvement programs is the development of productive hybrids. Since inbred lines are the basic ingredients of hybrids, state experiment stations and the U.S.D.A. release these inbreds to seed producers and seed stocks organizations who ultimately use them directly or indirectly in hybrids for commercial production.

Commercial Corn Improvement Programs

The scope of commercial corn breeding programs varies with the size and financial status of the company and with the skill and training of the individuals conducting the research. Some companies that do little or no actual corn breeding advertise their testing programs specifically for promotional purposes. Many small companies depend primarily on experiment stations and the U.S.D.A. for new inbred lines. They incorporate these new lines with older released lines to make new hybrids to best fit their needs. Larger companies with more facilities and more trained breeders develop their own inbred lines. However, they also may use 1 to 4 experiment station inbreds to make certain hybrids.

Inbred lines developed by a commercial concern are seldom exchanged with other concerns. Therefore, most hybrids developed by a particular company are combinations of inbred lines developed by their breeders with inbred lines from state and federal experiment stations.

DEVELOPMENT OF HYBRID CORN

History

Prior to the development and use of hybrid corn, corn improvement followed this pattern: (1) mass selection, 1870-1920; (2) varietal hybridization, 1880-1920; (3) ear-to-row tests, 1900-1920; and (4) selection and development of inbred lines and eventually hybrids, 1900 to the present.
(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.

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.
The significance of each of the above procedures will not be discussed here but interested readers may obtain such information in various books, bulletins and articles on crop breeding.

**Hand Pollination Technique**

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. The method is illustrated on pages 6 and 7.

**Development and Selection of Inbred Lines**

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 in the original material. The resulting inbreds become more uniform in each sub-

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*Ear before pollination showing silk attachment.*

*Close-up showing silk attachment before pollination.*

*Apron used in hand pollination. Contains cut-back knife, shoot bags, pencil, notebook, and tassel bags.*
1. A glassine bag is placed over ear shoot at this stage, just before silks emerge.

2. Glassine bag in place over ear shoot.

3. Ear shoot is cut back the day previous to pollination.

4. Ear shoot 24 hours after cutting back; uniform silk brush has grown out ready for pollination.
sequent generation of selfing. The lines usually are very uniform after 5 to 7 generations of selfing. Plant variability thereafter is due mainly to differences caused by environmental factors.

Many undesirable characteristics hidden by continuous crossing in the open-pollinated variety make their appearance as selfing proceeds. Examples are the inability to produce the essential green chlorophyll (which results in white seedling 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 3 to 5 generations of inbreeding), they may be tested to determine their 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 varieties or hybrids. Thousands of lines may be produced but only a few prove to be superior. Testing procedures are designed to identify these few outstanding inbred lines.

**Evaluation of New 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.

**Prediction and Testing of Double Crosses**

Once the performance of the single crosses among a number of lines is known, it is possible...
to predict the performance of a hybrid made up of any 4 of the inbreds with a fair degree of accuracy. It has been demonstrated that the characteristics of any double cross hybrid (A x B), (C xD), will approximate the average of the 4 single crosses (of the 6 possible among 4 lines) that are non-parental, namely (A x C), (A x D), (B x C), and (B x D). For example, the yield of US 13, whose pedigree is (WF9 x 38-11) (L317 x Hy), will approximate the average yields of the 4 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 10 inbred lines. The work involved in making up seed of the 630 double crosses and testing would be prohibitive. Their performance may be estimated with reasonable accuracy by testing the 45 single crosses and using these data to predict the performance of the double crosses. A small number of double crosses selected on the basis of 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 and 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, these tests should be conducted for at least 3 years.

Types of Hybrids and Their Performances

Hybrids are classified into single, double and multiple crosses and as suggested by their nomenclature they contain 2, 4, and more than 4 inbred lines, respectively. Usually greater variability in the resulting cross can be expected as more inbreds are added. Data obtained by various workers indicate that yield reductions occur in descending order from single, double, to multiple crosses. Synthetic crosses are advanced generations of multiple hybrids and seed is usually increased by open pollination or random sib pollination between different plants by hand pollination.

Comparative Yields of First Generation with Advanced Generation Seed

Inquiries often are received concerning the planting of seed from a commercial crop of hybrid corn. One usually can expect a yield reduction of about 10 to 25 percent from such use. With the small cost for hybrid seed, farmers are advised not to use advanced generation seed. Hybrid seed costs range from $1.25 to $3.00 per acre, depending on planting rates and the market price of hybrid seed. Three or four extra bushels of corn at $1.00 per bushel will more than pay for first generation seed.

Cytoplasmic Male Sterility

The procedure of detasseling certain rows in the production of hybrid seed will be discussed in detail later but the introduction of male sterility into certain inbreds makes it possible to produce hybrid seed without detasseling. This is accomplished by making one inbred line of a double cross cytoplasmic male sterile. For example, to produce the double cross US 13 (WF9 x 38-11) (L317 x Hy), the inbred WF9 would be made male sterile by crossing on a cytoplasmic male sterile stock and back crossing by normal WF9.
By continuous backcrossing, i.e., by crossing sterile plants in successive generations with WF9, a sterile WF9 will be developed. Usually this can be accomplished in from 5 to 7 generations. Seed for the male sterile WF9 is then maintained by crossing to the original WF9. When the male sterile WF9 is pollinated with 38-11, the resulting F₁ is sterile and will not require detasseling. Certain inbred lines carry pollen restorer genes and whenever these inbreds are used on male sterile lines, the resulting F₁ cross produces functional pollen. Such restorer genes are necessary in the male single cross of a double cross to insure adequate pollen in the commercial crop. At the present time pollen restorer genes are being introduced into the male single cross parents of hybrids, but in the meantime it is necessary for seed producers to blend seed of a hybrid produced by the male sterile method with seed of the same hybrid produced by the conventional method. The most common procedure is to plant 4 of the 6 female single cross rows with male sterile single cross seed and the other 2 with its fertile counterpart. Only the latter 2 rows will require detasseling, thus reducing detasseling 66 2/3 percent. At harvest the seed is bulked and the processing operations such as drying, shelling, and grading are handled as one unit to insure satisfactory blending. The use of the cytoplasmic male sterile method reduces the cost of production to some extent but more important is its convenience to the seed producer. Detasseling is a task that must be performed regardless of weather and often it is difficult to obtain workers who will continue the task in wet or very hot weather.

Breeding for Insect Resistance

It has been demonstrated that corn inbreds and hybrids differ in tolerance to insects and that a greater tolerance and resistance can be bred into present day hybrids. The progress of breeding for resistance to corn insects has been almost directly proportional to the development in techniques of artificial infestations and has been slow where it is necessary for breeders to depend upon natural infestations. A second hindrance is a lack of knowledge pertaining to the mechanism of resistance to damage by most insects. In the case of breeding for resistance to corn earworm, knowledge of the mechanism of resistance would be very beneficial.

The usual procedure in breeding for insect resistance is to locate the most resistant line and cross
it with the inbred to which resistance is to be added and following this with a series of backcrosses to that inbred. The progeny of these back crosses are subjected to either natural or artificial infestations and the most resistant plants are selected.

Corn insects causing losses in Missouri, in order of importance are: (1) corn earworm; (2) European corn borer; (3) corn rootworm (northern and southern); (4) chinch bugs; and (5) aphids.

Although sources of resistance or tolerance to many of these insects have been located, the incorporation of resistance into hybrids adapted to Missouri has been slow. Recently new hybrids with tolerance to European Corn borer have been made available to Corn Belt farmers. One such hybrid is AES 801 which has demonstrated little stalk lodging and few dropped ears under heavy infestations of this insect.

Breeding for Disease Resistance

Breeding for disease resistance in corn is slightly more advanced than is breeding for insect resistance. This probably has been due primarily to a greater advancement of artificial inoculation techniques for some diseases.

Corn diseases can be classified under those that affect: (1) seedlings, (2) roots, (3) stalks, (4) leaves, (5) tassels, and (6) ears. Some diseases may attack more than one part of the plant. For example, smut may attack any part of the plant above the ground.

The corn diseases that cause most of the damage to corn in Missouri are: (1) leaf blights and (2) stalk rots. Root and seedling diseases, ear rots, smut, crazy-top, and black bundle disease are found some seasons more than others. Usually smut is more prevalent under drouthy conditions.

The leaf blights are caused by either the two fungi Helminthosporium maydis and H. turcicum or the bacterium, Bacterium stewartii. Bacterial wilt is transmitted from plant to plant by the flea beetle. The amount of bacterial wilt is usually correlated

Comparison of susceptible strain with one resistant to root lodging.

Comparison of semi-dwarf type inbred line with a normal type.

Top, inbred strain susceptible to corn earworm. Bottom, inbred strain showing resistance to corn earworm.
closely with the number of flea beetles that over-winter. If winters are cold during December, January, and February, and few flea beetles over-winter, bacterial wilt will not be so prevalent the following summer. Good sources of resistance to the leaf blight diseases have been found, and many resistant hybrids are now being placed into production.

Stalk rots are caused by Diplodia zeae, Gibberella zeae, charcoal rot, species of Pythium spp., and occasionally by a bacterium. It is believed the first three organisms are responsible for most of the stalk lodging in Missouri.

Most of the ear rots in Missouri are caused by Diplodia, Gibberella, or Nigrospora, with others of somewhat lesser importance such as Penicillium and Aspergillus.

**SEED PRODUCTION**

**Foundation Seed Stocks**

It is very essential that single cross seed stocks be authentic in their genetic identity and purity. The resulting double cross cannot be any better than its parental single crosses, and for the grower's protection, it is highly recommended that only certified single cross seed stocks be used. Lists of certified single cross seed producers can be obtained from various agricultural experiment stations. Many of the experiment stations have affiliated foundation seed stock organizations. Most of these organizations are nonprofit corporations under the supervision of the director of the experiment station formed mainly to produce single crosses involving nonreleased inbred lines.

A small seed producer may grow his own single cross seed stocks but usually it is more economical for him to purchase them from reliable organizations that specialize in producing this type of seed. Most of the large seed producers grow all or a part of their foundation seed stocks, depending upon the number of privately owned inbreds that are involved.

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 percent. For example, in case of a sample with 80 percent 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 cross 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 soil fertility and anticipated environmental conditions of the growing season. The usual
ratio for double cross seed production is 2 rows of the male single cross to 6 rows of the female single cross. The number of seeds per pound may vary from 1000 to 2000 with an average of about 1500.

The amounts of seed of the male and female single crosses needed to plant one acre for double cross production are given in Table 2.

Using figures from Table 2, a 20-acre double cross 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.

<table>
<thead>
<tr>
<th>Plants Per Acre</th>
<th>Amounts of Seed Required</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>8,000</td>
<td>1-1/3 , 4</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10,000</td>
<td>1-2/3 , 5</td>
<td></td>
<td></td>
</tr>
<tr>
<td>12,000</td>
<td>2 , 6</td>
<td></td>
<td></td>
</tr>
<tr>
<td>14,000</td>
<td>2 1/3 , 7</td>
<td></td>
<td></td>
</tr>
<tr>
<td>16,000</td>
<td>2 2/3 , 8</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Cultural Practices

The cultural practices suited to general field corn production apply equally well to the production of hybrid seed corn, with the exception of time and depth of planting. Single cross 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, which, under Missouri conditions, 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 the germination of the seed, or about 1 1/2 inches. Many poor stands are the result of planting too deep.

Planting

Under ordinary weather conditions the ratio of 2 rows of the male single cross to 6 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 pollenation period more pollen rows may be necessary, and a ratio of 2 male rows to 4 female rows may be more satisfactory.

A 2 to 6 ratio is convenient when a 4-row planter is used. One of the outside planter boxes is filled with seed of the male single cross and the other 3 boxes with seed of the female single cross and each round trip of planting will provide 2 and 6 rows, respectively, of the male and female single crosses. When the 2 to 4 ratio is used, the male rows can be planted with a 2-row planter and the female rows with a 4-row planter. If a 4-row planter only is used, the planter boxes must be shifted.

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

Table 3 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>
<thead>
<tr>
<th>Plants Per Acre</th>
<th>36&quot; Rows</th>
<th>38&quot; Rows</th>
<th>40&quot; Rows</th>
<th>42&quot; Rows</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number</td>
<td>inches</td>
<td>inches</td>
<td>inches</td>
<td>inches</td>
</tr>
<tr>
<td>8,000</td>
<td>21-3/4</td>
<td>20-1/2</td>
<td>19-1/2</td>
<td>18-2/3</td>
</tr>
<tr>
<td>10,000</td>
<td>17-1/3</td>
<td>16-1/2</td>
<td>15-2/3</td>
<td>14-3/4</td>
</tr>
<tr>
<td>12,000</td>
<td>14-1/2</td>
<td>13-3/4</td>
<td>13</td>
<td>12-1/3</td>
</tr>
<tr>
<td>14,000</td>
<td>12-1/3</td>
<td>11-3/4</td>
<td>11-1/4</td>
<td>10-2/3</td>
</tr>
<tr>
<td>16,000</td>
<td>11</td>
<td>10-1/4</td>
<td>9-3/4</td>
<td>9-1/5</td>
</tr>
</tbody>
</table>

Isolation

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

The seed producer must provide adequate isolation and then hope for an abundance of pollen of the male parent at the proper time. Table 4 gives the isolation requirements for certification taken from the Regulations and Standards for Seed Certification, published by the Missouri Seed Improvement Association.

<table>
<thead>
<tr>
<th>TABLE 4 -- ISOLATION OF DOUBLE-CROSS SEED PRODUCTION FIELDS TO QUALIFY FOR CERTIFICATION (SWEET OR POPCORN MUST BE 80 RODS AWAY.)</th>
</tr>
</thead>
<tbody>
<tr>
<td>When the number of acres in the crossing field is</td>
</tr>
<tr>
<td>9 or less</td>
</tr>
<tr>
<td>ft.</td>
</tr>
<tr>
<td>-------</td>
</tr>
<tr>
<td>650</td>
</tr>
<tr>
<td>610</td>
</tr>
<tr>
<td>578</td>
</tr>
<tr>
<td>528</td>
</tr>
<tr>
<td>495</td>
</tr>
<tr>
<td>445</td>
</tr>
<tr>
<td>413</td>
</tr>
<tr>
<td>363</td>
</tr>
<tr>
<td>330</td>
</tr>
<tr>
<td>280</td>
</tr>
<tr>
<td>248</td>
</tr>
<tr>
<td>198</td>
</tr>
<tr>
<td>165</td>
</tr>
<tr>
<td>------</td>
</tr>
</tbody>
</table>

*If less than 50 feet must have 24 border rows.
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 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 cross 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 lower 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 percent of the ear parent plants have shed pollen after the silks are showing, or
b. If the total for any 3 inspection dates exceeds 2 percent. Sucker (tiller) 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 0.1 percent definitely off-type and/or volunteer plants, or more than 2 percent doubtful plants in the pollen parent rows.

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 and 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 from poor traction in wet weather. It is rather difficult to shift laborers from a riding to a walking job in case the machine cannot be used.

Small reductions in yield may result when leaves are removed with tassel. The removal of a leaf from a tall vigorous plant is less injurious than removal from a small plant. Experimental data indicate a reduction of from 2 to 3 percent in grain yield from the removal of 1 leaf and about twice this amount when 2 leaves are removed.

Harvesting

Only the seed from the detasseled (or male sterile) rows is hybrid seed. This may be harvested either by hand or with a mechanical picker. The most desirable mechanical picker is the 2 row mounted type which will harvest 2 rows without disturbing the adjacent ones. Machines of this type
permit removing the pairs of male rows. This eliminates any chance for the mixing of ears from male rows with those of the female rows, which are harvested later. 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 percent when harvesting is begun, and drying facilities should be available if the moisture content is above 20 percent. A mechanical picker damages the seed considerably when the moisture content exceeds 30 percent. Many producers in Missouri allow the seed to dry in the field to a moisture content of 16 to 18 percent 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 grain moth.

Sorting

Corn ears from the picker may be passed over another set of husking rolls to remove any remaining husks or silks. The ears often then pass over a moving belt or a table for hand sorting and the removal of damaged and diseased kernels from ears that are only partly defective. This is much easier 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 pile of ears in a bin or special crib. The air is forced up through the corn from a slotted or screened bottom bin with air tight sides. The exhaust air from the top of the bin may be diverted through another bin in the opposite direction, or merely allowed to escape, if it carries too much moisture. 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 circulator fan.

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

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

Drying may be accomplished by forcing unheated air through a bin of corn. This eliminates the fire hazard and saves the heating cost but the rate of drying is decreased considerably. Several manufac-
turers specialize in equipment for drying grain.

The moisture content of the grain 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 Agricultural Experiment Station indicated that there was much less damage to corn shelled with 12 percent moisture than with 7.6 percent 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 6 grades.

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

**Seed Treatment**

Seed treatment of corn is most effective when the seed is planted in cold, wet soil, under conditions unfavorable for germination and seedling growth but favorable for development of seed decay and seedling diseases. Treatment is particularly effective if the seed is damaged by handling or from kernel rotting organisms. Since the weather following planting cannot be predicted, it is advisable to plant treated seed because the cost of seed treatment is very low in comparison with the probable benefits from the net return over a period of years.

Several seed treatment chemicals are on the market, but only two, Arasan and Captan, are now recommended for corn seed treatment in Missouri. Since the seedcoats of corn are smooth, the materials must be applied either with a sticker to help coat the seed with the chemical dust, or by the slurry method. Slurry treatment consists of applying the material in a water suspension. Slurry treatment is best made with specially developed seed treatment machines, but it can be applied 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.

**Bagging and Storage**

Seed corn is usually marketed in bushel bags containing 56 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 or heavy paper. The Missouri Seed Improvement Association 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 percent and then stored at a temperature as low as possible, preferably less than 70°F. Such temperatures help to retain viability and greatly retard insect activity.

**Sales and Delivery**

Most hybrid seed is sold directly to farmers by salesmen employed by the seed firms, rather than through retail seed stores. Retail stores handling hybrid seed corn quite often sell other farm and garden seeds as well as farm implements and supplies. Most of retail stores purchase seed directly from the seed producer or seed company.

The salesman often is a successful farmer who is likely to sell seed corn to his neighbors based on how well he is liked rather than on the merits of the hybrids he is selling. The usual method is for the salesman to contact a farmer, make the sale, and arrange to either have the farmer pick up the seed later at the salesman's headquarters or in some cases has it delivered. The active salesman contacts his customers throughout the growing season and, if the seed proves satisfactory, prospects are good for an early order for next year. Salesmen are usually paid a commission for each bushel sold.

**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?

Recommended lists of open-pedigree 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 Missouri Agricultural Experiment Station Bulletin 673, Corn Hybrids for Missouri.