PRACTICAL METHODS OF PLANT BREEDING.

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1686

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The increasing interest in plant-breeding is one of the most striking characteristics of modern agricultural conditions. Only a few years ago it was thought that almost any kind of seed would do to sow. Most of the selection, or breeding, that was done was of a haphazard, very unscientific nature. It was scarcely realized that any but Luther Burbank and a few other geniuses could carry on careful, systematic breeding of any value. Few were enough interested to even think of it. Now all is changed. The country, especially in the corn belt, is traversed by special trains carrying lecturers who inform the farmers of the best methods of improving their crops. Scientific men all over this and other countries are studying the principles which underlie the breeding of plants. They are striving to discover the best methods of applying these principles in the field.

Careful breeding of animals has been in progress for many years, and yet many things are obscure or unknown about it. It is, then, no great wonder that so little is certainly known concerning plant-breeding.

Yet even our meager knowledge of principles and proper methods is of great economic value. A small increase in yield per plant or per acre will in the aggregate of the entire country amount to astonishing figures in the case of our staple crops. When we remember that it is only the marginal fraction of the crop which furnishes the profit to the grower---the rest being used to cover expenses---then it is that we realize the advantage to him who has a variety which, from its inherent productiveness, yields more than the average, be it only one or two bushels per acre. A small increase of this kind would often double a farmer's actual profit.

With these preliminary observations to establish the money value of plant breeding, we will pass to a consideration of where and how it should be done.

Degree of moisture, kind of soil, and general climatic conditions have a great effect upon a plant's development, and unless the plant has been grown under given conditions for several generations, until it has become acclimated or adapted to those conditions, it is not usually fitted for the best possible growth. There are apparently some exceptions to this general rule. Some plants do better from seed raised under conditions best suited to the development of that given crop, and seed should be imported each year, or at least at short intervals, from that locality. In such cases, of course, the breeding of the crop will be done only in the locality adapted to its growth. Most such instances will be found among garden vegetables and flowers, however, and in these the average Kansan is not interested to such an extent as in the cereals. Among the latter, our Red Texas Oats appear to illustrate to a certain extent the fact just mentioned. Many farmers find their seed "running out" after a few years, and think it an advantage to secure new seed from Texas. Experiments go to show that in this case, however, a very little care in breeding the crop here will result in a variety better fitted for our conditions than even the seed brought direct from Texas. Our grains in general are found to do better, other circumstances being equal, from home grown seed than from seed brought from any great distance. Especially true is this of corn. Good corn taken from eastern to western Kansas will produce scarcely anything the first few years. These facts suggest the necessity of breeding seed grain in the vicinity in which it is to be sown. If it were not for this, the experiment stations might as well conduct practically all of the breeding

operations, and furnish the growers with seed every two or three years. They could be better fitted for carrying on the work than the average farmer, and could produce more exact and valuable results. There would then be but one or two methods worth useing in breeding each kind of grain. As it is, methods must needs be several to meet varying conditions, for no one will be best for all. They will comprise selection of various degrees of complexity, cross-pollination, and hybridization, with various combinations of these means to improvment.

The simplest method of plant breeding is selection by the fanning mill, or seed grader method. This method alone is of much value, and may be adopted by those who think they cannot afford a more elaborate method. The large, plump seed only should be sown. This aids in insuring strong plants and hence better yields. Experiments have usually shown that this method will very materially improve a strain in a few years. It might be added in passing, that with plants whose object is not the production of seed, it is not always considered advisable to select the seed in this way. For instance, where extreme earliness is desired in tomatoes, seed somewhat immature is sometimes selected. However, if such methods are practised very long the resulting loss of vigor over balances the gain in earliness. With wheat, oats and other small grains, such methods would never pay. Besides selecting large, plump, well matured grain for seed, the crop should always be given as good conditions for growth as possible, as the highest standard cannot otherwise be attained. This rule applies to all methods of breeding and should never be overlooked.

A slight advance on this first method of selection is the selection of seed ears of corn from the crib. The main advance of this over the preceeding method, is that whole ears are taken into account

in place of the individual grains. The butts and tips should be discarded in order that the grains may be of uniform size and shape. Heads of wheat and other grain could similarly be selected after harvest. This, however, is scarcely advisable in view of the advantages of the next step forward and its slight extra labor and expense. This is selection in the field before harvest. A more or less accurate knowledge may thus be obtained of the good or bad characteristics of the whole plant and the conditions under which it has grown. Good ears of corn, for instance, will not be considered relatively as valuable when grown under especially favorable conditions as similar ears grown under more crowded and unfavorable circumstances. Two good ears on one stalk will be preferred to but one, which is slightly better individually. Or again, an ear good in itself may be discarded because of serious faults in the stalk. In the case of wheat, oats, etc., it is more difficult to determine the relative worth of individual heads by this method, yet it seems certain to be of sufficient benefit to warrant its adoption where more intricate methods are not feasible. One of the especially valuable points over preceeding methods is the pureness of the type which may be obtained.

So far we have mentioned only methods of selecting seed from the general crop to produce the next general crop. We now come to breeding plot methods though yet referring mainly to simple selection. In the simplest breeding plot method an especially rigid selection of seed is made and a comparatively small plot planted from this very best seed. From this plot is saved each year the very best seed for next year's breeding plot, and the next best seed for the general crop. In the case of plants which cross fertilize, this breeding plot should be placed either in an isolated spot or else in one edge of the general crop of the same variety away from the prevailing wind. The

location of breeding plots of self-fertilized plants is not so important, but the soil should be good and well prepared.

Where plants are naturally cross-pollinated there is some danger of too close inbreeding by following this method year after year. In the case of corn this danger is remedied somewhat by planting each ear in the breeding plot separately, one ear to the row, and then detasseling each alternate row. Any rows that are very poor should also be detasseled. The detasseling is done by grasping the tassel just as it emerges from the sheath and before it has begun to shed pollen, and pulling it loose at the first joint. Seed is saved only from the detasseled rows, which insures that the seed has been "cross" rather than "close" pollinated. Seed should be saved from each of a large percentage of the detasseled rows, as in this way there will be less danger of inbreeding.

Any of the preceeding methods are more or less adapted to the ordinary farmer, depending somewhat, it is true, upon the size of his farm and the amount of each kind of grain he raises. Some of the methods mentioned may appear to involve a great deal of work, and in fact they do, but the results are so great as to fully repay the outlay of labor and time.

We now pass to methods little adapted to any but large breeders or Experiment Station workers. First among these we will mention is the centgener method which has been especially well developed by Prof. Willet M. Hays, at the Minn. Station, in the breeding of wheat. A large number of good kernels are selected and planted one in a place at a given distance apart each way, usually either six or eight inches. By this means the plants are separated sufficiently to be distinguished individually. Each plant also has as near an equal chance with its fellows as possible. It has exactly the same space,

and to the extent that the soil is of a homogeneous nature throughout, it has an equal chance at fertility. Thus, in so far as lies within human control, each plant has an equal chance to show its inherent qualities, and the best producer should give rise to the best producing offspring. With plants separated as in this method, selection may be made for other qualities; e.g. height of stalk, rust resistance etc. The plants appearing best from the field inspection are each put into a bag by itself, taken to the seed house, and thee grain from each plant determined separately. Then one hundred grains from each of as many of the best plants as the station can handle are planted in centgeners, the grains either six or eight inches apart each way. Each centgener has a border of other grain, so that the various centgeners will not be mixed. The centgener of one hundred plants should give a good idea of the value inherent in the strain resulting from any one grain, and seed for the third years planting is saved only from a few of the very best centgeners. The selection by centgeners may continue indefinitely, but whenever desired the remainder of the seed may be saved for the multiplying plot. Several improved varieties or strains have been introduced by this method. It is sometimes found that the strains which do best in the centgener plots do not do as well, relatively, under actual field conditions where they are more crowded. This introduces an element of chance in the work. Nevertheless, it is believed that the results attained have many times repaid the expense involved. Plants which are naturally cross pollinated are not adapted to this method, but wheat, oats, barley, etc. are suited to it.

The next to be considered is the head and ear test method. We think this a better method than the preceding in many respects. Heads of wheat, oats, barley, etc. are selected from their general size and

appearance the first year. Each head is planted in a row by itself. The result is very interesting. Some rows produce very poorly and others exceptionally well. This method gives a better chance to compare the productive power of different heads or strains, than does the centgener method. The latter depends more on the individual plant; the head test method selects for multiplication the head which is able to make the best production record. The method of planting the centgener plots is also more tedious than the head test rows. Heads may be selected from a few of the best rows for the next year's head test plot, and the remainder of the seed from one or more of the best rows may be saved for the multiplying plot. For plants which are naturally "close" or "self"-fertilized this method is an excellent one, but for plants like corn which should be cross pollinated, a rather complicated system must be adopted to obtain best results, although the ear test is used as the foundation. The most noted of the systems of corn breeding are the Illinois and the Ohio plans.

The Illinois plan is explained in Bul. No. 100, of the Ill. Sta. and the Ohio plan in Circular No. 53. of the Ohio Sta. Both are too extended and intricate for a complete discussion within the limits of this paper. In the Illinois plan, the breeding plot is divided into quarters, twenty-four ears being planted in each quarter, and each ear in a row by itself. In both plans each alternate row is detasseled and seed saved only from detasseled rows. By the Illinois plan the plot is mathematically arranged each year so as to avoid inbreeding to the utmost. In fact this mathematical exactness is one of its most serious faults. It does not allow enough latitude for planting the very best ears next each other. The best row from which seed is to be saved may be planted next to, and pollinated by, an ear-row, which, although good, is not nearly the equal of its mate. The Illinois plan

is strictly a line breeding scheme, and after the strain is once established does not allow of the introduction of ears from outside sources. The Ohio plan overcomes some of the objections to the Illinois plan but has its own faults. The first year ears are selected which appear to be good, but they are tested before being placed in the breeding plot. A portion of each ear is planted in an ear row test plot, and the remainder of the ear is labeled to correspond with its number in the ear row test and is then laid away until the next year. The next year the remainder of the ears which proved to be the highest producers are planted side by side in the breeding plot. The best ear row from which the seed is to be saved will then be side by side , and hence largely pollinated, with the pollen of another highest yielding ear row. Only the remnants of the ears which proved in the ear row test to be quite superior are planted at all in the breeding plot. The main objections to the Ohio system would seem to be the waste of a large portion of the good ears in determining their value, and the possibility of too close inbreeding. The latter objection is somewhat overcome by admitting to the ear row test plot, registered ears from other breeders, as well as ears from the breeding plot, multiplying plot, and general field. It would seem as though it might be an advantage to plant the rows in the breeding plot which were to be detasseled for seed, from ears which had not been previously tested. This would afford a saving of time and seed and only those rows which were found to be the highest yielding need be used in furnishing seed for the multiplying plot. Of course there would be a slight loss of advantage,too, in that the very best ears might not be just side by side, but the best ear rows from wnich the seed is to be saved would be sure to be pollinated by high yielding sire rows.

Perhaps a further word should be said concerning the ear row

tests. These are in duplicate, and besides, check rows are planted after each fifth row. The yields used in determining the value of an ear are not the actual yields, but the calculated relative yields, thus eliminating the effects of environment. Only ears are planted in the test plot which have previously shown a high vitality, otherwise poor germinating ears would be handicapped at the start. Seed having poor vitality is never desirable.

Next to be mentioned is cross pollination and hybridization, by hand. By the former we mean the crossing of two plants of the same variety. By hybridization, although it may not be the best use of the term, we mean the crossing of two varieties of the same species.

Cross pollination sometimes gives greater vigor when applied to naturally self-fertilized plants and sometimes does not. It is sometimes resorted to and should be mentioned as one of the methods which are practical in the hands of an expert. Cross pollination by hand is sometimes used with naturally cross pollinated plants in an effort to secure an espacially pure type. In all such hand work, the flowers must be covered early enough and long enough to prevent the entrance of foreign pollen except as applied by the breeder. In plants whose flowers contain both stamens and carpels in the same flower, the stamens must be carefully removed before they begin to shed pollen. Hybridization is an important method of plant breeding. Results are very uncertain, yet it may be counted as practical with the patient, painstaking expert. The operator should have a clear conception of the result sought and should cross varieties which are likely to give rise to the desired combination of characters. After the hybrids have been obtained, selection must be employed to complete the task.

We have now mentioned in a general way the principle methods of plant breeding with special reference to the cereals for which our

great state is so well adapted. To the writer it seems certain that the increasing use of better breeding methods will, within a few years, elevate Kansas agriculture to a much higher level. The boys of the state are being interested in corn breeding. They should also be encouraged to breed other grains. Perhaps some of them could be interested in plant breeding by being presented with a package of hybridized potato seed. Perchance they would obtain nothing of value, but the varied assortment resulting is sure to be interesting.

In conclusion, we wish to repeat that our seed grains should be bred in the vicinity in which they are to be sown. Let each farmer adopt as good a method as possible. Or the farmers in a community may select one of their number to raise their seed grain for them if they are willing to pay a good price for it. If there is no good seed at home, some may be sent for to begin with, but after that breed, it at home and have it thoroughly adapted to home conditions. And finally, the more thorough, the more exact, and the more intelligent the breeding, the more valuable the result.