THE USE AND VALUE OF BACK-CROSSES IN SMALL-GRAIN BREEDING

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BACK-CROSSES have long been used in animal breeding to fix desired characters in cattle, horses, or other live stock. Despite any bad effects of inbreeding, back-crossing has been one of the best methods of retaining desired variations of conformation or other intangible complex characters.

So far as the writers know, back-crosses have not been used in small grains to secure definite types in the progeny. They have been used to study inheritance and incidentally have entered into the complex hybrids made more frequently by early plant breeders than at present. They seem to have been largely if not entirely neglected in any definite breeding programs to produce progeny of specific types, in spite of the fact that most small grains are self-fertilized and hence are immune to the evil effects of inbreeding. On the other hand there has been a nearly universal assumption that desired types are to be selected from the F_2 progeny of matings of suitable parents. Recently there has been a widespread feeling that large numbers should be used.

The writers feel that there is an important place for back-crosses in small grain breeding that is not now fully appreciated. It must be acknowledged at the same time that the barley projects here discussed are not yet far enough advanced to be entirely satisfactory as examples. The results to date, however, are so promising and the method so plausible that others working with small grains may find it worth considering when breeding for definite ends.

Smooth-Awned Barley

One of the barley projects now under way is the production of varieties with smooth awns. This is of especial interest because both the large generation and the back-cross methods have been and are being tried. The extensive co-operative breeding work at the Minnesota Agricultural Experiment Station was carried on by selections in the F_2 and later generations. This work is being continued. At two other experiment stations the production of smooth-awned barleys is an important project. The production of high-yielding smooth-awned varieties is of much importance. The rough awns are objectionable both in harvesting the crop and in feeding the straw. They definitely limit the acreage of barley in places where the acre yield of feed from barley exceeds that of the crop grown in preference.

Several smooth-awned barleys have been imported into the United States. Most of these are black, six-rowed, hulled varieties. Crosses with these and the American commercial varieties were first made by the senior author in 1911 and 1912. In 1913 an F_2 population was grown at St. Paul, Minn., in co-operation with the Minnesota Agricultural Experiment Station. In later years other F_2 populations were grown and a large number of segregates tested. The crosses at St. Paul were with barleys of the Manchuria type. In the Western States, hybrids with the barleys adapted to arid regions were made. Although the stocks of smooth-awned barleys available for hybridization were inferior in yield to Manchuria or the Western forms, out of a cross of smooth-awned × Club Mariout a smooth-awned segregate was found equal to the Club Mariout parent in yield. This work was done at Moro, Oregon, in co-operation with the Oregon Agricultural Experiment Station. At St. Paul, Minn., no segregates of the Manchuria × smooth-awn crosses have so far been equal to the Manchuria in yield. As the senior author has previously stated,[1] it is unlikely that a parent is ever exactly recovered among the segregates of a cross and it is probable that weaknesses not found in the Manchuria parent were present in all segregates tested.

In 1920 it occurred to the senior author that, as all that was desired was a smooth-awned Manchuria, this character could be effectively transferred to the best Manchuria strain by backcrossing. C. I. No. 2330 (Minn. No. 184), the best Manchuria selection developed by the Minnesota Agricultural Experiment Station, was used as the Manchuria parent. A white six-rowed smooth-awned segregate from a previous cross was used as the smooth-awned parent. This segregate was homozygous for smooth awns and was one of the best of those tested at Minnesota. It was already partly of Manchuria "blood."

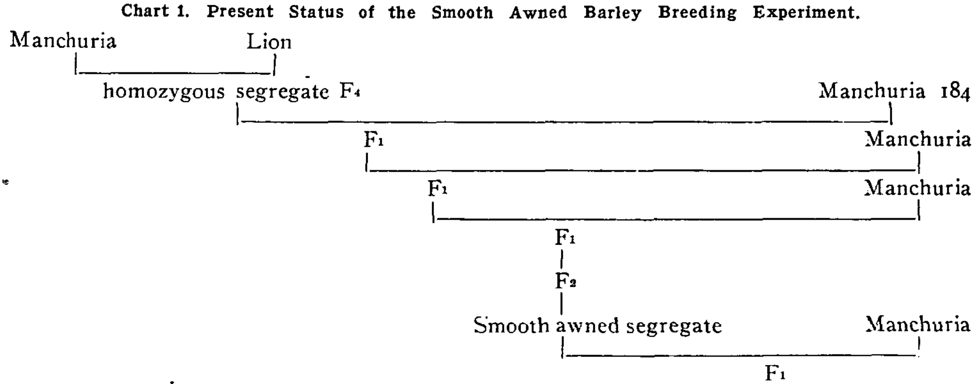
In the winter of 1920-21 the parents were crossed in the greenhouse at Arlington Experiment Farm, Rosslyn, Va. The F_1 of this cross was grown at Aberdeen, Idaho, in 1921, where it was recrossed with C. I. No. 2330, the Manchuria parent. The recrossed seed was sown in the greenhouse in the fall of 1921 and the F_2 generation grown at Aberdeen in 1922. A smooth-awned segregate in 1922 was crossed again with C. I. No. 2330 and the resulting seed sown in the greenhouse. The status of this project today is shown graphically below.

Results Obtained to Date

Already the barley looks more like Manchuria than any obtained previously from other crosses. It has been obtained quickly and inexpensively, as the numbers used were very small. It is in a way a project where the breeding of resistance to diseases occurring in Minnesota has been a factor and where the actual work has been done remote from this environment. It will be interesting to note if resistance can be obtained under such conditions.

This opens the question of the relative value of the two methods of breeding. This in turn brings up the large question of the reason for the lack of complete success in the earlier attempts. In this case the object is to obtain a smooth-awned barley as good as Minnesota No. 184 (C. I. No. 2330). From the smooth-awned parent we want only the smooth awns. All the

Chart 1. Present Status of the Smooth Awned Barley Breeding Experiment.



[1] Harlan, Harry V. Smooth-awned barleys. *Journ. Amer. Soc. Agron.* Vol. XII, Nos. 6-7, 1920, pp. 205-208.

other characters, morphological and physiological, are desired from the Manchuria parent. How feasible it may be to secure by recombination the characters of a parent is difficult to answer. Inheritance studies necessarily involve characters that can be measured or evaluated. Most of these are morphological in nature. Occasionally a physiological detail of metabolism becomes evident through chance, as when anthocyan colors are formed. The number of variations in metabolism which are not thus revealed cannot even be guessed at, but must be large. We do know that variations in the protoplasmic complex are inherited. That the difference of the cell content of varieties is evidenced in many ways, such as the treatment necessary to coagulate the proteids of wort from barley, the variations in milling quality in wheat, and recently by the specialized forms of rust. Following the lead of Dr. Stakman, 37 specialized forms of stem rust now are known and the number seems limited only by the facilities for testing. These forms are largely differentiated by the reaction of different strains of wheat to them. This means that there now are known 37 different heritable protoplasmic complexes of wheat that have to do with rust resistance. It is probable that several times that number actually exist. There must also be many heritable variations of cell content not associated with rust resistance but associated with the vigor and yielding power of the plant and with the nature of the proteids in the grain which may be of importance in milling, malting, or other commercial use.

At any rate, in the mating of two parents there is an indefinite number of heritable physiological characters that will combine in an unknown number of combinations and the nature of these combinations cannot be determined by an inspection of the plants, as is the case with morphological characters. We are thus breeding for characters we cannot see and whose numbers we do not know. This brings up the question of probabilities. If we are dealing with an unknown number if invisible characters, what is the chance of securing a segregate that has all the Manchuria characters except roughness of awns? When our pathologists get under way on the leaf and root fungi detrimental to barley it is probable that they can equal in number the rapidly increasing parasites of wheat. When to the number of different protoplasmic complexes shown by disease susceptibility is added those differences which must be associated with other heritable qualities the number of non-visible factors may reach into the hundreds. If there were only 20, the breeding by the use of large numbers would be impossible, assuming that all 20 of the physiological characters of Manchuria are superior to those of Lion for conditions in Minnesota, and that these are inherited independently. There would be just one chance in 1,048,576 that the 20 desirable Manchuria characters would be found in any segregate and one chance in four that this segregate would be smooth-awned if found.

It obviously would be impossible to grow such a generation or to discover the desired plant if grown. On the other hand, in back-crossing, if the 20 characters are inherited independently, there is a rapid elimination of those coming from the Lion parent. With each recross the Lion "blood" is reduced one-half; in five back matings only one-sixty-fourth of the blood is not Manchuria and that one-sixty-fourth is heterozygous with only one chance in 128 of any one factor being finally other than Manchuria. That is, if there were 20 independently inherited factors the expectancy would be for 108 out of 128 plants to be entirely homozygous for Manchuria characters and the remaining 20 to be heterozygous for only a single character. It should be possible here to select the plant desired.

Linkage a Limiting Factor

These assumptions are based on independent inheritance. The assumption of independent inheritance is no more justified than the assumption of as few as 20 characters. It is probable that these factors are linked in groups and that the groups are fewer than 20 regardless of the total number of factors. This assumption, while decidedly influencing the results obtainable, does not change the method of procedure. If linkage is presumed, it is logical to presume that some of the objectionable characters of Lion are linked with the smooth-awned factor. If this is the case it limits the achievement of all methods of breeding and if the linkage cannot be broken down the best that can be achieved will be smooth-awned barleys homozygous for the factors of Manchuria except those with which the smooth awn is linked in Lion. This point, if it is the limit, should be more easily reached by back-crossing than by selection from an extensive F_2 generation.

There is no reason to believe that linkage is at all an insurmountable barrier. Other smooth-awned parents could be used in which more desirable characters might be linked with smooth awns than in Lion. Also linkage is far from absolute. In the continued back-crossing there is opportunity for cross-overs to break up the undesirable group. As the Manchuria parent is repeatedly used, cross-overs must include desirable characters, which is not necessarily the case in the later generations of the heterozygous elements of the cross when not back-crossed. In many plants the evidence of linkage is so slight as to indicate a very great number of cross-overs.

Whatever the explanation, it would seem that on this project the easiest approach to the point limited by linkage is by back-crosses and that the greatest opportunity for profitable cross-overs is afforded by the same method. In the smooth-awned project the smoothness of the awns is not being modified by the repeated back-crossing. The F_2 plant segregated out in 1922 had awns as smooth as those of the parent used in 1920.

The writers have one or two other breeding projects where the same method is being used and it would seem especially serviceable in such problems as changing the color of otherwise desirable varieties and in securing earliness while retaining the varietal characters.

Group, Race, and Nation

THE GROUP MIND, a sketch of the principles of collective psychology with some attempt to apply them to the interpretation of national life and character, by WILLIAM MCDOUGALL, F. R. S., Professor of Psychology at Harvard University. Pp. 418. New York, G. P. Putnam's Sons, 1920.

One of the distinguishing features of Dr. McDougall's extremely interesting book is the sound eugenic theory which runs through it. The eugenist must be profoundly concerned with many of the facts of collective psychology, since he is dependent on them to get carried into effect the principles which he realizes as essential in any permanent and good government. Dr. McDougall has, from the psychological side, made many helpful contributions to eugenics, and the present volume, which is a sort of sequel to his widely-known *Introduction to Social Psychology,* deserves wide reading.—*P. P.*