# AMERICAN BREEDERS' ASSOCIATION

## VOLUME V

REPORT OF THE MEETING HELD AT COLUMBIA, MO.
JANUARY 6, 7 and 8, 1909
AND FOR THE YEAR ENDING DECEMBER 31, 1908

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nary horse, at their station near Washington, is an example of the line of work which would be stimulated were the zoölogical parks in the country to combine in an attempt to get in animals with the special view to their use for breeding purposes. Considerable interest would be aroused, I understand from my talks with animal breeders, if the short-nosed cattle of Chile, the various races of Indian cattle, the hardy monkeys from Manchuria or the large-horned sheep of Sardinia were introduced in such a way that they could be used for breeding purposes. Unless some systematic effort of this kind is made, both for plants and animals, I predict that many valuable forms will become so rare that all possibility of domesticating them or using them in the creation of new forms will be excluded. What immense natural resources lie in a single cultivated plant or domesticated animal, and what a disgraceful impression our neglect to preserve from extinction races or species of plants and animals, will make on the generation of human beings which follows. In considering the conservation of our natural resources the preservation of reproducable forms of life from absolute extinction appears to me as one of the most important. The practice of the strictest economy in the use of coal will not preserve indefinitely the coal measures but the preservation of a plant or animal species from extinction will place future generations in the possession of material from which great forests, vast orchards or great forage areas can be recreated or new races of cultivated animals adapted possibly to conditions where now our domestic races of animals are not able to survive.

This is the general aspect of the situation as it appears to the writer and it seems to me that the American Breeders Association is the organization to emphasize and encourage a movement for the building up of permanent collections of plants and animals for the use of breeders.

## A PURE-LINE METHOD IN CORN BREEDING.

By Dr. George Harrison Shull.

Cold Spring Harbor, N. Y.

Last year I described[1] a series of experiments with Indian corn which led me to the conclusions (1) that in an ordinary field of corn the individuals are generally very complex hybrids; (2) that the deterioration which takes place as a result of self-fertilization is due to the gradual

[1] The Composition of a Field of Maize. Report American Breeders' Association, 4: 296–301, 1908.

reduction of the strain to a homozygous condition; and (3) that the object of the corn-breeder should not be to find the best pure-line, but to find and maintain the best hybrid combination.

The continuation of these studies during the past year have given still further proof of the correctness of the first two of these propositions, and besides has given unexpected suggestions for a new method of corn breeding by which the essential feature of the third proposition may be realized. It is my purpose to discuss this new method briefly in the following pages. I will first, however, describe the results of the past year's experiments in so far as they bear upon the points in which we are interested here. For convenience I will refer to the two self-fertilized families contrasted in my paper last year as "Strain A" and "Strain B." It will be remembered that these two families resulted from the self-fertilization of different apparently equal individuals; but that notwithstanding this fact, they differed from each other in height and stockiness of stems, width and greenness of the leaves, length of shank of the ears, appendages of the husks, quality of the grains, and the number of rows of grains on the ears. (See fig. 1.)

In addition to the parallel cultures of self-fertilized and cross-fertilized families which have been continued from the beginning of these experiments in 1904, I had during the past season the $F_1$ offspring of a cross between two sibs in Strain A, and two families representing reciprocal crosses between Strain A and Strain B. It was observed that every one of the mentioned characteristics which distinguished Strains A and B, remained constant distinguishing features in the pure-bred families, but in regard to the number of rows on the ears, it is now obvious that Strain A has the normal mean number, 8, as compared with 14 in Strain B, for in this year 89 per cent of the ears produced by Strain A had only 8 rows of grain, though the selection of ears for seed in this strain during three years was for 12 rows on the ear, and only in the last year was an 8-rowed ear used because a suitable 12-rowed ear was not available. This result is a striking confirmation of the suggestion made last year that according to the law of regression the occurrence of a mean number of rows less than 12 in Strain A indicated that the normal number of rows for this strain is 10 or possibly only 8.

The cross between two sibs in Strain A was grown beside the self-fertilized family belonging to the same strain, and these two families were so similar during the entire period of their development that they were considered identical, but at the end of the season it was found that the cross-bred family was a trifle taller and produced over 30 per cent more

FIG. 1. TYPICAL SPECIMENS OF STRAIN A (AT RIGHT) AND STRAIN B (LEFT), SHOWING CONTRAST OF VEGETATIVE CHARACTERS. DRAWN BY J. MARION SHULL FROM A PHOTOGRAPH.

grain by weight than the self-fertilized family. In the self-fertilized family, 73 ears were produced, weighing 12 lbs., and in the cross between sibs the 78 ears weighed 16½ lbs. There was also a striking difference between these two families as regards variability in the number of the rows on the ear, as may be seen in this table:

| NUMBER OF ROWS ON THE EAR | 8 | 10 | 12 | 14 |
|---|---|---|---|---|
| Self-fertilized | *65* | 6 | 2 | 0 |
| Cross-fertilized | 8 | *50* | 19 | 1 |

Unfortunately the parents of these two families were not identical in the number of rows, the mother of the self-fertilized family having 8 rows and that of the cross-fertilized family 10. The greater height, greater weight of grain produced, the higher number of rows on the ears, and the greater variability in the number of rows, in the cross-fertilized family, all point to the same conclusion, namely, that my self-fertilized Strain A was not yet reduced completely to a homozygous condition, and that the parents, or at least one of them, of my cross-bred family was heterozygous.

The two families which were the product of reciprocal crosses between Strain A and Strain B, have proved of great interest, for although the individuals of both Strain A and Strain B were small and weak, and the self-fertilized families of these produced respectively only 12 lbs. and 13 lbs. of ear-corn, the hybrid family in which Strain A supplied the mother and Strain B the father produced 92 ears weighing 48 lbs., and the reciprocal cross produced 100 ears weighing 55 lbs. Typical ears of Strain A and Strain B, and of their reciprocal hybrids may be compared in Fig. 2. If we reduce these results to bushels per acre on the basis of 10,000 ears per acre and 70 lbs. per bushel, it is found that Cross A × B has produced 74.4 bushels per acre and Cross B × A has produced 78.6 bushels per acre, the average for the two families being nearly 77 bushels per acre. The two families which I have kept continuously cross-bred during the period in which these experiments have been in progress, and which have been likewise continually selected to 12 and 14 rows of grains, may be properly taken as controls. These two families together produced 203 ears weighing 107½ lbs., or at the rate of 75 bushels per acre, and when the comparison is extended so as to include my other continuously crossed families—8 families in all—it is found that these produced collectively at the rate of a little less than 75 bushels per acre.

My farmer friends, especially here in the heart of the corn country, will not be greatly impressed with these yields of 75–78 bushels per acre, but I must call attention to the facts that the light gravelly soil of Long Island bears a very unfavorable comparison with Mississippi valley alluvium for the production of Indian corn, and further that the summer of 1908 was notable for one of the longest periods without rain that has ever been experienced there. The important point will not

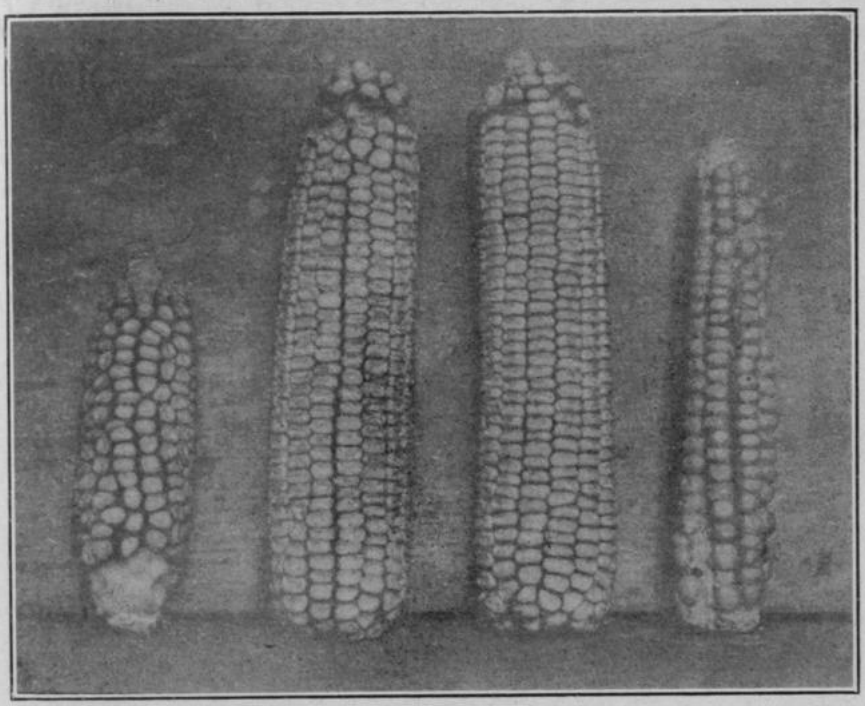

FIG. 2. TYPICAL EARS OF STRAIN A (AT RIGHT) AND STRAIN B (LEFT) AND OF THEIR RECIPROCAL HYBRIDS. EACH HYBRID STANDS NEAREST ITS MOTHER-STRAIN.

be missed, however, that the crosses between two self-fertilized strains yielded a little more grain than those strains which had been kept carefully cross-fertilized by hand. To be sure, the difference is not great enough to seem of any particular significance in itself, but it must be remembered that the two self-fertilized strains, A and B, have been essentially unselected, being simply those two strains which have first approached the pure homozygous state as a result of self-fertilization. It is scarcely conceivable that other pure strains crossed together should

not give in certain combinations considerably greater yields than those produced by the combination of Strains A and B. At any rate the result is sufficiently striking to suggest that the method of separating and recombining definite pure-lines may perhaps give results quite worth striving for.

This suggestion will be more readily appreciated perhaps if I discuss briefly the theoretical aspect of this method of pure-line breeding as compared with the method now in use among the most careful corn-breeders. In the light of my results, the constant precautions that are taken in the method now in use, to prevent in-breeding, have for their real object the retention of the most efficient degree of heterozygosis or hybridity, and it is obvious that the selection of the most vigorous individuals for seed, really picks out those individuals which have this most efficient degree of hybridity. While I have not investigated the inheritance of the various characteristics of the pure lines of maize and am not in position to say that they all follow Mendel's law, many investigations of particular characteristics in corn have shown that those characteristics are Mendelian. Even if some of the differentiating characteristics of corn should not prove to be Mendelian, it seems not improper to discuss the two methods on the Mendelian basis.

In the method which selects for seed the most heterozygous individuals, the characteristic splitting and recombination of unit-characters must produce an offspring of quite various degrees of heterozygosis. Some individuals will be as complex as the selected parents, others will have many of the same units in the homozygous condition, and thus be less complex and consequently less vigorous. According to the laws of chance a few individuals in the field may be expected to be almost or quite completely homozygous, and as a result will be very inferior in vigor and will produce but little grain. The result of such a process must always be to give a crop of lower average yield than the average of the selected seed. Moreover, these different combinations of unit-characters and different degrees of hybridity in the offspring of a complex hybrid must introduce a certain amount of heterogeneity into the crop which will have the effect to also lower the average quality with respect to any other desirable points which have been used as guides in the selection of the seed-corn, and efforts at the attainment of homogeneity by the method now in use tend to lessen physiological vigor, and therefore lessen the yield, owing to the fact that such homogeneity in the offspring of hybrids is to be attained only through homozygosis in respect to all those characteristics which affect the form and size of the ear, width,

depth, shape, and composition of the grains, and any other feature in which homogeneity may be desired. This is doubtless the explanation of the interesting experience related by Mr. Joseph I. Wing at the meeting of the American Breeders' Association in Columbus two years ago. His father had selected a very fine deep-grained variety of corn in which great uniformity had been attained, but only at the expense of decreased yield.

In the pure-line method outlined below all individuals in the field will be $F_1$ hybrids between the same two homozygous strains, and there are theoretical grounds for expecting that both in yield and uniformity superior results should be secured. Thus, every individual will be as complex as every other one and should produce an equal yield of grain if given an equal environmental opportunity, so that in so far as hereditary influences are concerned the vigor of the entire crop should be equal to the best plants produced by the methods now in use. This would seem to result necessarily in a larger yield than can be produced by the present method. But not only will all the plants in the field have the same degree of complexity, but will all be made up of the same combination of hereditary elements, and consequently there must result such uniformity as is at present unknown in corn.

With such a prospect as this, I believe we will be sufficiently interested to make the discussion of the method by which such results are to be attained worth while. The natural question arises as to whether the technique of the new method will be sufficiently simple to make it practicable. To this question I believe I can safely answer that the pure-line method will be considered simpler than the elaborate ones now in use among the most careful breeders, e. g., those at the Illinois, Connecticut, and Ohio State Experiment Stations. The process may be considered under two heads: (1) Finding the best pure-lines; and (2) The practical use of the pure-lines in the production of seed-corn.

(1) In finding the best pure-lines it will be necessary to make as many self-fertilizations as practicable, and to continue these year after year until the homozygous state is nearly or quite attained. Then all possible crosses are to be made among these different pure strains and the $F_1$ plants coming from each such cross are to be grown in the form of an ear-to-the-row test, each row being the product of a different cross. These cross-bred rows are then studied as to yield and the possession of other desirable qualities. One combination will be best suited for one purpose, another for another purpose. Thus, if the self-fertilized strains be designated by the letters of the alphabet, it may be found that the

Cross C × H will give 120 bushels per acre of high-protein corn, that F × L produces a similar yield of low-protein corn, that K × C gives the highest oil-content accompanied by high yield, and so on. Moreover, it seems not improbable that different combinations may be found to give the best results in different localities and on different types of soils. The exchange of pure-bred strains among the various experiment stations greatly increases the number of different possible hybrid combinations and facilitates the finding of the best combination for each locality and condition.

(2) After having found the right pair of pure strains for the attainment of any desired result in the way of yield and quality, the method of producing seed-corn for the general crop is a very simple though some-

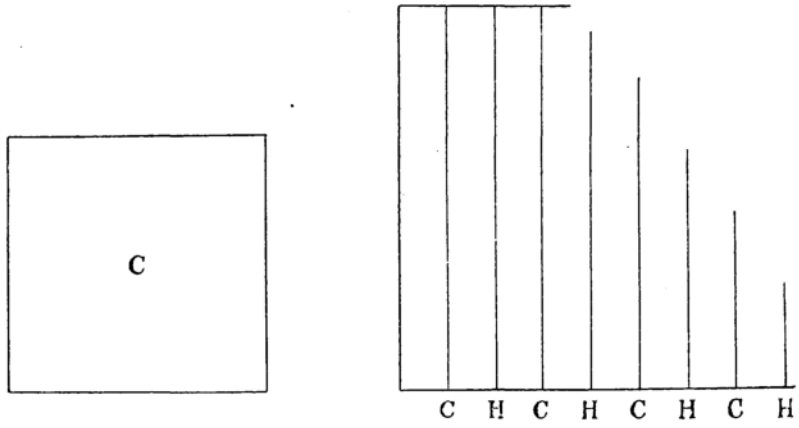


FIG. 3. ARRANGEMENT OF THE TWO ISOLATED PLOTS FOR THE PURE-LINE METHOD OF CORN BREEDING.

what costly process. Two isolated plots will be necessary, to which I may conveniently refer as Plot I and Plot II. See Fig. 3. In Plot I will be grown year after year only that pure strain which investigation has proved to be the best mother-strain for the attainment of the desired end. Thus, if it has been found, as in the example already cited, that Cross C × H gives the desired result, Plot I will be occupied by Strain C. This will require no attention from the breeder's point of view except that any exceptionally vigorous or aberrant individuals should be eliminated, as such plants might be safely assumed to be the result of a foreign pollination. In Plot II, Strain C and Strain H are to be planted in alternate rows, and all of Strain C is to be detasseled at the appropriate time. All the grain gathered from the detasseled rows will be seed-corn for the general field-crop, and that gathered from the tasseled rows will be pure-bred Strain H to be used again the following year in

the same way. Here again in pure Strain H all exceptionally vigorous or aberrant individuals should be discarded as being probably due to the entrance of foreign pollen.

I am not prepared at present to say what will be the probable cost of seed-corn when produced by this method, but have reason to suppose that it would be more expensive than by the present method; nor can I surmise what relation this increased cost will bear to the increased yield that will be produced. These are practical questions which lie wholly outside my own field of experimentation, but I am hoping that the Agricultural Experiment Stations in the corn-belt will undertake some experiments calculated to test the practical value of the pure-line method here outlined.

## IMPROVEMENT IN GUERNSEY CATTLE.

By W. H. CALDWELL, *Peterboro, N. H.*

I regret in attempting to trace the improvement that has been made in Guernsey cattle that time will not allow a portrayal of the many interesting and vital conditions that have contributed to the settlement and development of the wonderful island—Guernsey—the home of the breed.

The group to which this island belongs, known as the Channel, or at one time called Alderney Isles, has had a most important place in the history of the civilization of the world. Their insular position separated as they are by those bits of silvery sea from England and the continent, dangerous of approach, well fortified, it is no wonder we find on them a sturdy race of people who take pride in conquests. Guernsey points with pride to Jersey that she was never conquered, while Jersey has never forgiven her sister for being a few miles nearer the London market.

It is to these two islands that we as breeders of dairy cattle owe much for the foundation of the two breeds of cattle so well known as producers of dairy products of the highest quality.

Right here, before taking up especially the Guernsey I wish to refer to the term which has in the past been often applied in rather a promiscuous manner to the cattle of this group—Alderneys.

Before the age of steam the chief trade of the Channel Islands with England was carried on by vessels that sailed between St. Malo, Brest and other ports on the French coast to England, On the voyages to London, Plymouth or Portsmouth these touched in turn at St. Heliero,