MAIZE

SELECTION AND BREEDING

-- 1937 - 1938 --

By

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1937 - 1938.
ACKNOWLEDGMENTS

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PART I. INTRODUCTION.

The problem of the selection and breeding of improved strains of maize has been studied sporadically at the Imperial College since 1928, and has now assumed the aspect of a breeding programme rather than an experimental investigation. This does not mean that the study of maize improvement has been concluded in all but practical detail; however, so much is known of the methods and theoretical questions involved, that the subject has become almost a matter of routine.

In the circumstances therefore, it is felt that the investigation offers little scope for the activities of future Post-graduate workers; and one of the main purposes of the present paper will be to build up the experience of the past ten years into a breeding policy, capable of forming part of the normal farm routine.

Welch (13 p. 32) pointed out that a programme could be mapped out involving production and testing of pure lines, and gave a daily diary (13 p. lxxvii) which, subject to slight modification, has proved very satisfactory this season. It will be seen from this that an automatic system can be adopted, involving initiating, breeding and testing pure lines, and culminating in a hybridisation policy.

In the past two years, methods have been tried and experience gained in the handling of such an undertaking, and it is now possible to formulate rules of procedure. These are, of course, not rigid, and it is to be expected that modifications will occur, but as they have been of value in the past, they will at least form a guide for the future.

Theoretical considerations have been dealt with so adequately by previous workers (7, 13) that it seems redundant to include much beyond a review of current literature and more
recent experimental work in the present paper. Theoretical points upon which the author holds a different view are discussed; but for a complete account of this aspect of maize breeding the reader is referred to the excellent and complete account in Welch (13) and in U.S.D.A. Yearbook, 1936 (5).

From a practical point of view, the problem offers little in the way of original work since there is so limited an amount of material. Neither Mass Selections nor Pure Lines, except Harland's strains, have been subject to more than two seasons' work and it is early to think even of testing their value. Such small tests as were carried out must therefore be taken with caution, and considered only as an indication rather than a proof.

There is, of course, but one test of the value of any variety or hybrid - the performance of its progeny. This will form a regular part of the routine if the proposals outlined below are adopted.

Much of the present paper is concerned with details of procedure and of proposed plans for a regular breeding programme - in fact, it hopes to achieve the position of a practical text-book for the College Maize Breeding, based on the theories of all previous contributions in this series, and the methods they found satisfactory.

The present author considers that, on purely economic grounds, there is no future for hybrid corn in Trinidad. American work, cited below, (12) shows quite definitely that hybrid corn is better than the best mass selected types; but that it is more expensive to produce, can hardly be doubted. Now maize in Trinidad is almost entirely a peasant crop, grown on small holdings as a rule, and with seed saved from last season or bought for food, from a grower like the I.C.T.A. farm.
The use of hybrid seed depends for its efficiency on a fresh supply every year, either from the original seedsman or from the farmer himself, if he is competent to run a small area for the production of crossed seed. The latter is quite impossible for the majority of Trinidad maize growers, who have neither the ability nor the space to carry on such work. The former is a job for a specialised seedsman, and though Government might undertake this, the price would compare very unfavourably with food corn prices. It will be exceedingly difficult to persuade a grower of less than an acre of corn to pay extra for special seed.

The economics of mass selected seed are, on the other hand, quite different. The process is simple and easily demonstrated: the cultivator himself can, with very little trouble, ensure continuity of selection and hence prevent degeneration. For the larger grower it is less expensive to produce special seed corn than hybridisation and he can sell at prices more nearly corresponding to ordinary food corn.

While these considerations should be borne in mind, it would be unwise to condemn a hybridisation policy at the College on purely economic grounds. The problem has a definite agricultural value and it should provide valuable experience in the future as part of the Diploma course.
A full account of the theory of Mass Selection was given by Welch (13 p.4) and is therefore unnecessary here. However, it was considered advisable to have a check on his opinion that a short husk selection was desirable for Trinidad, due to the very poor crop from his selection for this criterion. A very small number of suitable undamaged cobs was obtained from Field 27D, and it was thought that exposed cobs were more liable to the action of rain and attacks by birds and fungi.

To decide if continuance of this selection was justified by a higher yield for exposed cobs, an experiment was conducted to obtain an indication of yielding capacity of exposed and protected types. This was done on the 1st Mass Selection - cobs were brought into the farm unhusked and 50 groups of 10 cobs of each of the two types were chosen at random and weighed; intermediates being discarded.

The experiment showed that exposed gave 14.4% higher yield than well covered, - significance 1000 to 1.

It should be remembered that this experiment can only give an indication, no proof is forthcoming until a yield trial takes place, but Welch's view seems justified at least on the Field 21 crop. This crop was not subject to the adverse weather conditions of Field 27D, and it may be that in a very wet season the exposed selection is unsafe. In laying down variety trials this point should be remembered and, if possible, a wet season and a dry season trial held.

Welch cites Richey (8) as finding selection for doubles to be the only selection not reducing yield and he carried out a 'well planned' experiment to prove this. However well planned this experiment was statistically, it can only be concluded that
he was unjustified in confirming Richey's hypothesis on unselected material. It is quite likely that all the selections made would give an increased yield since they were from the best plants in the field and the original population was very mixed.

The other observation made by Welch on doubles selection, i.e. that this selection needs to be well manured and supplied with moisture, seems very reasonable. For the expression of a prolific character, good conditions are essential, since a cursory glance at a young maize crop will convince the observer that many plants produce two silks, whereas few mature two cobs.

A method of Mass Selection designed to deal with a qualitative problem is described by Brunson (2) in connection with popcorn in U.S.A. Ears for selection are marked distinctively, and then a small quantity from one side of the cob is shelled. A measured amount of grain is taken from each cob and 'popped', giving a figure for popping expansion; this being the required character. In the experiment, conditions of temperature and moisture and carefully standardised in order to obtain comparable results.

On a basis of selecting the highest 10 to 15% of popping expansion values, (seed being obtained from the unshelled portions of the cob) it has been found possible to raise the expansion value from 19 volumes to 26 volumes in 6 years. Subsequently, there has been little change in expansion values, indicating that an upper limit of selection has been reached.

Since a fairly close correlation \( r = -0.59 \pm 0.022 \) has been obtained between expansion and amount of soft starch in the kernel, it is now possible to use starch content of a few grains from each cob as a selection criterion. The correlation is negative, which means that low starch content indicates high popping expansion.
In these experiments, to avoid deleterious effects resulting from too close selection, a minimum of 50 cobs was used for seed purposes.

There is, at present, no premium of quality of any description in Trinidad, and therefore this work has no direct application; it does, however, illustrate a method of selecting for quality, and shows very clearly the improvement that can be effected by selection.
Maize for future selection may be grown either in a special selection plot of a convenient small size, or may be grown as a farm crop. Both systems were followed in the present season and when the author arrived in Trinidad, Fields 23, 25 and 27D were already sown with Mass Selections I, VI and VII, and V respectively.

When Field 24 had been chosen for the main breeding site, two small areas of approximately 2,000 square yards each were hand sown with the two remaining Mass Selections, III and IV. Though this latter method is much easier to handle at harvest time, in that the whole area may be inspected, and planting is much more regular when done on a small scale, yet it is not practicable to limit selection to such small plots, especially as it is the policy of the farm to use nothing but selected seed for crop purposes.

Isolation:

As far as possible, isolation of selection material, either in space or in time, should be aimed at, and fortunately with one exception, this was realised in the present season. The only two selections which matured together were, however, planted in the same Field, and this makes contamination certain - Field 25 with the two selections VI and VII. However, since it was decided to abandon selection VII and this was in the southern part of the field, the other selection should be fairly pure; the prevailing wind being Northerly.

The value of isolation must be remembered and it should be a rigid rule for further work that all Mass Selections be isolated.
Cultivation and Planting Procedure:

The type of land to grow selection material is a matter of opinion, and depends to a large extent upon what place in agriculture the crop is designed to fill. In Trinidad, where maize is grown mainly on peasant holdings and is not heavily manured, there seems no justification for using heavy dressings of artificial on experimental fields; the crop will eventually have to face hard conditions and it is reasonable to suppose that similar conditions in the breeding programme will produce the best type.

On the other hand, the crop should not be grown on impoverished land or it becomes rather difficult to get enough seed to continue the programme. This difficulty was experienced in the present season on Field 27D, which is involved in an experiment designed to keep up fertility without the use of any manure whatsoever. The crop was very poor indeed, and it was hard to get even the small amount of seed that has been retained for Selection VI.

It is recommended that a field in good heart be used for growing selection material in the future, so that the minimum of manuring may be necessary. On Field 24, where the two special plots of mass selection seed were sown, such conditions obtained, and it was possible to grow a good crop without recourse to artificial; the only treatment being Sunnhemp ploughed in as a green manure dressing. A further advantage of this system is that there is no doubt in the worker's mind, when harvesting, that he may be selecting a well manured plant rather than a genetically sound one. Soil heterogeneity cannot be allowed for of course, but inequality of manuring can be eliminated.
Planting, wherever possible, should be done by hand, using a planting chain - rows three feet apart and plants one foot six inches in the rows, has been found satisfactory. This is recommended because it makes for an even establishment, giving an equal chance to all plants, and at harvest, a hand planted field is easier to work in. The rows are clearer and thus facilitate even sampling of the area.

Singling is necessary to obtain an even plant and to give each individual plant an equal chance. Supplying, though a normal farm practice, should not be practised in selection work unless there is a poor establishment; it proves to be a waste of time, as none of the supplied plants is mature enough for seed purposes when the field is being harvested.

Apart from these recommendations, the usual farm routine of cultivation is necessary.

Harvesting:

Selection of seed has so far always been practised at harvest, as there is no conclusive evidence of a purely vegetative character correlated with yield. Indeed that there should be a single character associated with a result so complex as yield is unlikely.

It is usual to select seed corn from the standing crop in order to ensure a 'good' cob coming from a 'good' plant, and with one exception (Selection III) this system was followed in the present season.

Actual method used in selection varied with type of planting as quite obviously a large area cannot readily be sampled by one worker. Thus, in the selection of types I and VI, sample strips about 50 to 60 yards long were taken across the rows; this being about the distance a worker can remember good plants
and compare them mentally with new ones. In each row therefore, two cobs were selected, each being the 'best' in respect of the required criteria in the sample length of row.

Clearly this method does not give the 'best' cobs from the field, not only because the area is merely sampled, but also because one row may produce three or more cobs, all superior to those chosen from another row. What the method does assure, however, is evenness of sampling. The soil heterogeneity tends to be evened out and there is thus less risk of one small fertile area contributing most of the selected cobs. The existence of such an area of large cobs would prejudice a careful worker from choosing them for seed.

Where smaller areas are planted for selection, it is possible to cover the whole plot and get a closer approximation to the 'best' plants and cobs. This was the case in Field 24 where the 'doubles' selection (IV) was made by inspecting the row, and choosing the best two or three double cob plants for seed.

Selection on the threshing floor is not generally to be recommended except when it greatly facilitates the choosing of cobs of the desired type. It is preferable actually to see the cob on the plant and use plant type as an additional factor. The Low Row Number Selection (III) was however, originally made by Welch on the threshing floor and it is very much simpler to sort out a group of cobs when stripped for this criterion. Therefore, it was decided to follow the same procedure again and 100 cobs were chosen in this way.
Criteria:

Five Mass Selections have been retained for future work out of the seven left by Welch, his selections I, III, IV, V and VI. It is proposed to retain the same numbers and add a prefix: I.C.M., i.e. Imperial College Mass Selection, as the seed is now about to be distributed abroad.

The criteria adopted are as follows:

I.C.M. 1: Largest and heaviest cobs - irrespective of type - from good plants.
I.C.M. 3: Best cobs with 10 or 12 rows of grain.
I.C.M. 4: Best cobs from plants bearing two pickable ears.
I.C.M. 5: Cobs exposed at the tip.
I.C.M. 6: Cobs well protected at the tip by the husk.

Tests:

It is suggested elsewhere in this paper (p. 26) that there be a yield trial of these five types, or of such of them as are retained, in the season 1939-40; possibly repeated in the subsequent year for confirmation. No such trial was possible this year, since seed was not available from all the types at a convenient time, and also it was considered that a sufficiently homozygous state had not been reached to warrant a trial.

Two small tests of direction of selection were carried out from which general deductions may be drawn; the two types I.C.M. 3 and I.C.M. 4 were tested for percentage occurrence of the desired criteria. The method adopted was to take two random groups of twenty plants in each row, giving in all forty samples, and calculate the percentage occurrence of the type of cob required. It would be difficult to apply such a test to the other more vaguely defined selections and the only value of these results is for comparison by future workers so that they
may know if their material is being influenced in the desired direction.

<table>
<thead>
<tr>
<th>Selection</th>
<th>Desired type</th>
<th>Standard Error</th>
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<tbody>
<tr>
<td>I.C.M. 3</td>
<td>38.25</td>
<td>1.09</td>
</tr>
<tr>
<td>I.C.M. 4</td>
<td>12.88</td>
<td>1.01</td>
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Yields of Various Mass Selections: 1937-38

<table>
<thead>
<tr>
<th>Selection</th>
<th>Field</th>
<th>lbs. per acre (fresh cob)</th>
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<tbody>
<tr>
<td>I.C.M. 1</td>
<td>23</td>
<td>3918</td>
</tr>
<tr>
<td></td>
<td>21</td>
<td>4766</td>
</tr>
<tr>
<td>I.C.M. 3</td>
<td>24</td>
<td>4100 #</td>
</tr>
<tr>
<td>I.C.M. 4</td>
<td>24</td>
<td>3805 #</td>
</tr>
<tr>
<td>I.C.M. 5</td>
<td>27D</td>
<td>2082 #</td>
</tr>
<tr>
<td>I.C.M. 6</td>
<td>25</td>
<td>3403</td>
</tr>
</tbody>
</table>

# green manure only
PART III(a). THEORETICAL CONSIDERATIONS.

Hybrid vigour and synthesis of new strains.

An aspect of maize breeding which has escaped previous writers in this series, is Richey's Convergent Improvement hypothesis (9).

Commencing with two pure lines, (e.g. N and R) consider these to be crossed and subsequently back-crossed for a number of generations to one of the parents; the most vigorous plants always being selected.

The genotype of the recurring parent will be recovered in the series- $\frac{1}{2}$, $\frac{3}{4}$, $\frac{7}{8}$, $\frac{15}{16}$ etc, and selection of the most vigorous plants will retain some of the dominant favourable genes of the non-recurring parent; these latter will remain heterozygous as long as back-crossing takes place.

Selfing such a back-crossed line will give homogeneity for the recurring parent's genes, and also for some of those derived from the non-recurring parent. Such lines Richey termed 'recovered', and he expressed them as N(R').

Two reciprocally recovered lines - N(R') and R(N') - will differ in fewer genes than the original parent lines, and by repeating the programme, using the recovered lines as foundation stock, a gradual convergence into a single line should result. Such a line would carry all the desirable characters possible from both parents.

The hypothesis is based on the assumption that hybrid vigour is due to accumulation of dominant favourable genes which is the prevailing theory (13 p.ii). Richey states that such recovered lines show an increase in yield and in other desirable characters such as resistance to lodging. He concludes that
since selected back-crossing gives a higher yield than can be expected from simple back-crossing without selection, the excess yield may be ascribed to the retention of dominant favourable genes by selection. Hence, he argues, the dominant gene hypothesis of hybrid vigour, is correct.

This should be capable of confirmation at some future date at the College, using back-crosses started in 1936-37.

The work of Ashby on development in hybrid corn (13 p.vi) has recently been added to by Sprague (11) who has conducted experiments on rate of growth throughout the plant life. Dividing the growth period as follows:

1. fertilisation to maturation of the seed
2. germination and through early seedling stage
3. late seedling stage to maturity

he was able to show that hybrids grew faster in stages 1. and 2. than both parent lines, not equal to the more vigorous parent as Ashby suggests. A large error prevented a similar increase in stage 3. from being significant.

It was found that reciprocal hybrids were alike both in rate and in total amount of growth. Embryo weights however, within a genotype were found to be of little importance in determining weights of mature plants, since differences failed to persist. Sprague concludes that hybrid vigour is not a maintenance of initial difference size (Ashby's view) but is due to growth rate difference and entirely compatible with the dominant gene hypothesis.

Progeny tests

The behaviour of its progeny is the only test of the value of a pure line. Types of progeny test were discussed by Welch (13 p.29) who concludes that the best of these is the top-cross - a method simple in operation and enabling a fair estimate
of 'crossing value' to be obtained.

In practice a good open-pollinated variety is planted to windward of the pure lines to be tested - the latter are detasselled and thus all pollen comes from the open-pollinated variety. Hence all seed on pure line plants is related through the male parent and yields from such seed give an estimate of the crossing value of the female parent.

The adoption of this system is recommended at the College and provisions for it are outlined on page 26.

Hybrid corn production

Welch (13 p. 34) asserts that no advantage is gained by second-crossed seed since lower yields are to be expected. He does not make clear distinction between yields of second-crosses and yields from second-crosses.

Far from being "out of favour with American workers", second-crossed seed is the recommended practice in Iowa (3) where production of single-crossed seed is considered "somewhat more hazardous than the production of double-crossed seed". Second-crosses, for seed purposes, are favoured, not because of "the erroneous theory that heterosis was due entirely to the apposition of unlike genes at corresponding loci" (13 p. 34) but because they are the product of more vigorous and higher yielding plants, i.e. first-crosses.

Since it is suggested elsewhere (p. 27) that a commercial crossing plot should be instituted next year, an account of the practice of commercial crossing seems desirable. (3, & 10). The two parents of the cross are chosen, usually on their top-crossing performance, and they are planted out in alternating rows across the field. One of them is to provide pollen and is generally sown in single rows; the other (seed or female parent) is detasselled early and is usually sown in double rows.
From the single rows selfed seed results (apart from stray pollen), and from the double rows, the crossed seed is obtained. When favourable combinations have been established, the process is continued indefinitely using the parents alternately for seed production; the seed producing parent is maintained pure for that year in a normal hand selfed plot.

Second-crossed seed is produced similarly except that the ratio of seed rows to pollen rows is usually 4 to 1 instead of 2 to 1, presumably because the hybrid plants produce more pollen.

Results of Corn Tests

For several years American workers have carried out tests of hybrid open-pollinated varieties of maize and their findings have been set forth annually (1, 12).

In Illinois, (12) tests have been conducted for four years and the increase in types entered for testing has been remarkable.

<table>
<thead>
<tr>
<th>Year</th>
<th>Total Entries</th>
<th>Hybrid Entries</th>
<th>No. of Stations</th>
</tr>
</thead>
<tbody>
<tr>
<td>1934</td>
<td>177</td>
<td>132</td>
<td>12</td>
</tr>
<tr>
<td>1935</td>
<td>274</td>
<td>228</td>
<td>15</td>
</tr>
<tr>
<td>1936</td>
<td>234</td>
<td>196</td>
<td>21</td>
</tr>
<tr>
<td>1937</td>
<td>332</td>
<td>302</td>
<td>21</td>
</tr>
</tbody>
</table>

Both hybrids and open-pollinated varieties have been tested in stations scattered over the whole state and comparisons have been made using a performance rating compounded from resistance to lodging and yield of sound corn.

In all cases the five best hybrids have given a higher performance rating and a higher total yield than the five best open-pollinated varieties. Statistical proof of these figures is not available but an increased yield of 5 bushels is stated to be significant.
Average state yields:

1934 Hybrids gave 12.9 more bushels/acre than open-pollinated.
1935 " 13.4 " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " " 

In 1937, the average hybrid yields were 16.4% greater than the average open-pollinated variety yields, this being most marked in areas suffering from drought, and the best hybrid averaged 15.85 bushels/acre higher than the best open-pollinated variety.

Entries were divided into regular and experimental classes, (the same system being used in Illinois) and the latter were new hybrids or open-pollinated types of which not much seed was available; these gave the highest yields and performances in Iowa. The experiments were statistically designed but again no accurate account of significance is given.

Of interest is the observation that not all hybrids are good, some are below the lowest open-pollinated types in yield and performance rating. There seems to be a tendency for increased yields in hybrids to be due in part to increased moisture content, and this is looked on as being disadvantageous if a short ripening season occurs, it would probably lead to a much higher percentage of unsound corn.
There seems then, little doubt that hybrid corn gives increased yields in two of the principal corn states of the United States and it is claimed that the use of high yielding strains has increased the total production at least 1½ million bushels per annum in Iowa (4).

Uniformity.

The question of uniformity does not as yet affect Trinidad where there is no specialised maize trade. However, this seems to be one of the most important effects of the use of hybrid seed in America.

In the two specialised corn types, sweet corn and pop corn, there is a demand for a uniform product; particularly in sweet corn since canning has become so important, and hybrid corn has proved a definite advantage (2, 6).
PART III(b). CURRENT SESSION'S WORK.

Selection of Foundation Cobs.

20 foundation cobs were chosen from the open-pollinated crops this season. 10 of these were selected on plant characters at an early stage of growth, by the members of the First Year Class and details of their type and size are included in the year book.

The year book has been instituted to provide a permanent record, from year to year, of the various strains and crosses, and gives details of foundation cob (where known) and parentage. It should, in the future, give records of test yields obtained from top-crossing work.

Open-pollinated selected cobs from 1936-37

17 such cobs were left by the previous worker without details of type or size, they were grown in one block this season and as many plants were selfed as possible. At harvest, in all possible cases, three selfed cobs were chosen to commence pure lines from each foundation cob line; and 37 new lines were formed in this way.

Once selfed lines

119 once selfed pure lines were sown this season in 5 blocks of 18, 19, 16, 18 and 48 respectively. In all but the last, six plants were selfed, but in the 48 group it was only possible to self four plants. At harvest the best cob was chosen to continue the line unless this was very small, in which case, the two best were retained. Only two lines failed to produce seed but a number were diseased or malformed in some way.

No tests were employed on these lines due to their heterozygous condition but observations on their vigour are included in the year book and should be useful in future work.
Twice selfed lines

17 twice selfed lines were included and they gave most trouble from the start, germination was bad/one line failed to germinate. Two others failed to set seed and though it was hoped to secure top-crossed seed for a test next year, the yield from the whole plot was so discouraging, that the project had to be abandoned. Possibly conditions were unfavourable, but the whole plot produced only two lines equal to the best seven times selfed lines.

Three protogynous lines were sown with this group, one died out and the others set very poorly.

Seven times selfed lines

The Harland strains performed well and enough seed was collected from four of them to initiate a crossing experiment next year. Only one line died out and four lines were particularly good. The x strain seems to be most vigorous.

37011 which Welch was uncertain of, looks remarkably like a selfed line and is therefore probably Y₂.

No crossing was attempted, but some of the lines were used as pollen parents in back-crosses and second back-crosses.

Crosses

Many of the available crosses seemed to the author to be useless for testing or pure line production; their ancestral lines had, in some cases, been lost and they were thus incapable of repetition, even if valuable. It was possible in two cases only to compare existing lines in similar crosses, and x₇ and z₁ were found to be approximately equal while Y₂ was inferior to z₁.

Welch's back-crosses and 3-way crosses were selfed for the production of new lines and his back-crosses were also back-crossed again in persuance of the convergent improvement scheme.
New back-crosses and 3-way crosses were initiated and again all details are to be found in the year book.

The 4-way crosses and 3-way crosses to unlabelled pure lines were discarded, as it was felt they served no useful purpose in future work, having been made principally as a demonstration.

In addition to the year book mentioned above, pedigree sheets, commenced by Welch and made up-to-date, have been left in a separate folder. These are designed for continuous future use.
DETAILS OF METHODS.

As in the case of Mass Selection, it is suggested that a field in good heart be selected for breeding work and no recourse to artificialis be made.

Planting and cultivation

To facilitate later work, planting should be done in blocks of about 20 pure lines, this being the optimum number for handling when pollinating. One block of 48 lines was sown this season and proved very difficult to deal with adequately.

Planting 3 ft. x 3 ft. gives ample space for work and this season 50 plants of each strain were sown in two lines of 25 plants.

Singling is essential to obtain good sturdy plants, especially in lines that have been selfed two or more times - and the process should be carefully done to avoid injuring the plants retained.

Supplying is unnecessary and only produces plants maturing later than the average, and which therefore cannot be dealt with easily. This, of course, supposes a good germination and supplying may be essential if adverse conditions kill off a whole row or more.

Cultivation on normal farm lines was practised this year and when laying out plots, this should be borne in mind.

Pollination

Welch (13 p.lxxviii) gives a daily programme which is amended and included below as a practical guide; the modifications introduced in the present season were reduction in the number of pollinations and a labelling system.

Quite early in the season it was noted that little or no pollen was available after two pollinations, except in the cases where very young silks had been treated. It was therefore,
decided to reduce the number of pollinations to two and mark plants with a very young silk to be done a third time.

A system of coloured tag labels was introduced, under which each day had its appropriate colour, red, green, yellow and white. The small tags were affixed to the paper clips on the silk bags and the date of the first pollination was written on them.

On moving through the field, plants to be pollinated were easily distinguished from those completed and those done only one day previously, by the colour of the tag.

The modified programme was as follows:

Days:
1. Bag cobs of plants near to silking (A).
2. Bag tassels (A) and new silks (B).
3. Pollinate A - red labels. Bag tassels (B) and new silks (C).
4. Pollinate B - green labels. Bag tassels (C) and new silks (D).
5. Pollinate A and C - yellow labels. Bag tassels (D) and new silks (E).
6. Pollinate B and D - white labels. Bag tassels (E) and new silks (F).

After day 5, the first plants (A) are completed. (E) plants commence red labels again and another cycle starts. This system combines facility of working with the date labelling suggested by Welch as a help to grouping pure lines subsequently, for top-crossing. The length of time to silking varies markedly between pure lines, and it is advantageous when top-crossing to have all the lines mature approximately at once. Such data can be abstracted at harvest as each cob is dated and hence its sowing to selfing period is known.

Bagging technique was described by Welch but has been slightly modified in that a firmer joint is made in the silk bag.
if only one paper clip is used to fasten the edges of the bag, as below:

The tassel bag was fastened similarly and pollination technique was to slit along the outward edge of the bag bottom and shake pollen from the tassel bag through this slit on to the silk. Finally the cut edge was folded downwards (to avoid entry of water) and secured by two paper clips.

It is important to have strong paper clips or the bags will be blown away by the wind and for the same reason it is advisable to break off the subtending leaf and slip the bag well to the base of the cob before fastening.

No further treatment is essential before harvest, but it is desirable to remove bags after a fortnight or three weeks and tie the label with its clip to the cob with string. This allows quicker ripening and reduces insect damage.

Harvest

The purpose in retaining the labelling clip is for marking the cob at harvest. The long limb of the clip is straightened out and pushed into the butt of the cob so holding its label in place; the appropriate number being written on it.
One or two cobs per row were retained and shelled and the seed was packed in 1 lb. paper bags.

During the present season the services of the boy Boysie have been invaluable. He has done much of the practical work and, as he is fully acquainted with the problem, it is recommended that he is retained in the future.
PART IV.

A. Mass Selection

The author recommends that:

1. The five present selections be continued on the lines laid down on page 11.
2. No further reduction of their number be made until after testing.
3. No testing takes place until 1939-40.
4. Two full yield trials in the form of a Latin square or randomised block experiments to be laid down in 1939-40. These to be situated in the middle of a standing crop of maize and to take place in both wet and dry seasons.
5. At least the two best selections emerging from each of these experiments should be retained. This may mean that four selections would have to be kept at first, but it would prevent loss of a valuable type. (It is conceivable that the best wet season selection will not be the best dry season one).
6. Isolated seed plots must also be grown to maintain the selections.

B. Breeding

In the season 1938-39 it is recommended that:

1. About 15 to 20 fresh foundation cobs should be chosen.
2. The foundation cobs left by the author should give about 3 / their number of new pure lines.
3. The once selfed lines should be selfed again.
4. The twice selfed and three times selfed lines, or as many as deemed possible, should be top-crossed to I.C.M.1 in addition to selfing. (I.C.M.1 to windward of these plots).
(5) The Harland strains should be maintained, and also used in a crossing experiment to produce first crossed seed on commercial lines. This seed should be entered in the yield trials of 1939-40.

(6) Some Harland strain seed should be sown with the first and second back-crosses for further back-crossing.

(7) Hybrids selfed in 1937-38 should be observed carefully for good combinations and selfed again.

(8) 3-way crosses should be selfed for new pure line production.

In the season 1939-40 it is recommended that:

(1) The last season's programme (1) to (6) should be repeated with the new material available.

(2) Top-crosses from 1938-39 should be grown in a yield trial, randomised if possible (but this may be precluded by numbers) and half discarded.

(3) Second crosses on commercial lines should be made if two good first crosses are available, but first claim on 'commercial' first-crossed seed should be for the main yield trial.

(4) Back-crossing should be continued with the types available to provide eventually a test of Richey's hypothesis of convergent improvement.

Arrangement of work in the future

That the above suggestions, if adopted, would provide a considerable amount of practical work is fully realised by the present author. He also considers that important though the theory of the work may be, little contribution in the way of increased knowledge of a general nature can be expected from such a programme. The only results would be an application of already well-known theories and methods to Trinidad conditions, and ultimately, the production of improved maize for the local grower.
By reason of this belief, the author is led to suggest that the problem of Selection and Breeding of maize at the College should be handed over to the Diploma classes for continuance. They would be able collectively to supply much more work than a single post-graduate, and the dimensions of the problem are increasing so rapidly that too much field work seems inevitable. In addition, it would probably be a very valuable side of their work, bringing them into contact with a genuine breeding problem and providing statistical material.

Unless some such system is adopted, the maize breeding project at the College will occupy the activities of two post-graduate workers, without affording them much material for a dissertation.

Practical details in future work

It was suggested to the author that telescoping of two growing seasons into one session would be an advantage in the maize breeding problem. This is admitted, but the actual details of planting are probably better controlled by a competent authority than by the farm staff, as would be necessary in this case.

For example, the provision of pollen rows for top-crossing might well lead to confusion in planting. A good plan is to provide one row of a good open-pollinated variety (I.C.M. 1) to the windward of each pure line. The author considers that white numbered pegs, placed at the end of the pure line rows, would well repay their cost in convenience; the peg to be placed at the end of the southern row (for example) in all cases.

An early start in planting should be made in order to complete the programme and, if possible, the 'commercial' crossing plot should be sown first and given the benefit of 10 - 14 days clear of other maize planting.
SUMMARY

PART V.

1. The present paper makes no attempt to précis previous dissertations and is essentially practical in nature; theoretical considerations having been discussed by others in this series.

2. Modern work outside Trinidad is therefore dealt with mainly in its relation to the College programme.

3. Recent results from America are quoted, not as applying to local conditions, but as showing the type of activity desirable.

4. Considerable attention is given to practical methods in the hope that these may prove valuable guidance.

5. Both Mass Selection and Pure Line Breeding are dealt with though the author feels that the former is economically more sound.

6. It is agreed that Breeding work is useful training and recommendations are made to permit its continuance without occupying the time of post-graduate workers unduly.

7. Testing methods are outlined for future seasons and details for working them mapped out.

8. Five of Welch's Mass Selections have been maintained and seed stored for next season.

9. New pure lines have been initiated and the majority of existing ones maintained.

10. Bulking of Harland's strains has been possible and should enable a 'commercial' crossing plot to be started.

11. The author feels that the chief disadvantage of the present system of maize improvement at the College is its discontinuity and hopes that it will be found possible for a member of staff to hold a 'watching brief' over the programme.

12. In conclusion the author believes that no good can result from a sudden change in policy and reaffirms that patience is the chief attribute of a plant breeder.
REFERENCES

1. Agricultural Experiment Station, Iowa State College, Bull. 370, 1937. Iowa Corn Yield Tests.


APPENDIX I.

MATERIALS USED.

It is felt that a list of materials used in the 1937-38 breeding programme will be of use in the future. It is advisable to secure an adequate stock of the large paper bags used in selfing, as serious inconvenience was experienced this year when supplies were unobtainable. Any stout paper bag of 14 or 16 lb. will do for this process but the author particularly recommends the Tiger Craft ones which last very well, and are considered by the boy attached to the experiment, to be superior to those used by Purseglove and Welch.

Good paper clips are essential.

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<tr>
<th>Material</th>
<th>Amount used</th>
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<tr>
<td>14 lb. paper bags (Tiger Craft)</td>
<td>1,500</td>
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<tr>
<td>1 lb. &quot; &quot; &quot; &quot;</td>
<td>400</td>
</tr>
<tr>
<td>Paper clips (Oakville)</td>
<td>2,200</td>
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<tr>
<td>Manila labels</td>
<td>300</td>
</tr>
<tr>
<td>Coloured tags (Dennison)</td>
<td>4 bundles of each colour</td>
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<td>Balls of string (thin)</td>
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# APPENDIX 2.

**MATERIAL PUT IN COLD STORE.**

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<tr>
<td>I.C.M. 1</td>
<td>'Best' selection</td>
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<td>I.C.M. 3</td>
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<tr>
<td>I.C.M. 4</td>
<td>Doubles</td>
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<tr>
<td>I.C.M. 5</td>
<td>Exposed cobs</td>
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</tr>
<tr>
<td>I.C.M. 6</td>
<td>Protected cobs</td>
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<table>
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<tbody>
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<tr>
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<td>38021 - 039</td>
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<td>&quot; 3</td>
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</tr>
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<td>&quot; 11</td>
<td>38222 - 236</td>
</tr>
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APPENDIX 3.

OTHER DEPARTMENTS SUPPLIED WITH SEED

During the season requests for improved seed were received from Jamaica, British Guiana and Venezuela.

It was only possible to supply Mass Selection seed and this only in small quantities as below:

<table>
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<tr>
<th>Department</th>
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<th>I.C.M. 3</th>
<th>I.C.M. 4</th>
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<tbody>
<tr>
<td>Jamaica</td>
<td>4 lb.</td>
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<tr>
<td>British Guiana</td>
<td>4 &quot;</td>
<td>2 &quot;</td>
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<tr>
<td>Venezuela</td>
<td>5 &quot;</td>
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