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this purpose and plants spend 1 to 2 months in them before being hardened off and potted. When done efficiently, which is usually the case, this phase of the process can be accomplished with only negligible losses.

The success of the programme can rightly be described as spectacular. Highgate seed germinations have gone up from a yearly average of 20-25% to 60-65% and the output of plants of commercial potential at least doubled. Triploid germinations have increased similarly. Furthermore, it has been found possible to obtain plants of diploid crosses from which it was scarcely possible to obtain any progeny previously. For example, Paka x Sikuzani germinations have increased from a greenhouse average of 2% to over 30% by embryo culture.

Progress in the breeding of a new variety of banana to replace the much esteemed Gros Michel has always been severely retarded by three factors:

1. Poor seed set
2. Hopelessly inadequate seed germination
3. Failure to transmit adequate Panama Disease resistance to progeny.

Today, it can rightly be claimed that at least the second of these limiting factors has been eliminated.

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INBRED-HYBRID METHOD OF MAIZE IMPROVEMENT

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ABSTRACT

In spite of its limitations, the inbred-hybrid breeding system is the most extensively and successfully employed method of corn improvement in the United States. The breeding procedure consists of (1) isolation of inbred lines by selfing or inbreeding a few plants in each of the source populations which are open pollinated varieties or races, mass selected populations, synthetics or composites; (2) evaluation of inbred lines in top and single crosses; (3) crossing the chosen inbreds to produce highly vigorous and productive hybrids. Selection for desirable agronomic characteristics is practiced during the inbreeding process.

In our breeding programme in Jamaica, we are using this method to develop hybrid varieties which are adapted to low land tropical conditions. The selection emphasis is on the following traits:

1. High yield
2. Short plant stature with relatively low ear height
3. Ears with tight husks and strong shank
4. Resistance to lodging
5. Resistance to various leaf diseases like rust and blight
6. Resistance to chemical burns by herbicides and insecticides.

INTRODUCTION

Maize or Indian corn is a highly variable species with numerous races all of which are classified within a single diploid species *Zea mays* L. It belongs to a group of plants which are normally cross pollinated. Any open pollinated variety or population of maize is, therefore, a heterogenous assemblage of individuals no two of which are genetically identical. These genetically unlike individuals are potential sources of breeding material in any maize population.

Compared to temperate areas, the tropics are rich in diversity of maize types. Over 300 races, a great majority of which occur in the American tropics, have so far been described in a series of National Academy of Sciences - National Research Council publications on races of maize in various countries. In the United States, there are essentially two types of maize, Northern Flints and Southern Dents. The Corn Belt corn owes its origin to the hybridization of these two types. From this mixture, and with the inbred-hybrid breeding method, U. S. maize breeders have evolved hybrid varieties for the Corn Belt with a yield potential of over 200 bushels per acre. In the tropics, with numerous varieties at our disposal, it would appear that by employing the same methodology we should be able to do as good or even better than what breeders in the United States have done. However, tropical hybrid varieties of today do not have the yield potential of Corn Belt hybrid varieties. (In subsequent sections, we shall attempt to examine the reasons for this.)

1. *High Yield*: (This of course, is the first and foremost objective in any breeding programme).

2. *High Percentage of Amino Acids in the Grain*: Corn is notably deficient in two of the essential amino acids, lysine and tryptophane. This is the reason that corn meal has to be supplemented with soybean meal to make it a nutritionally balanced animal feed for monogastric animals. If by breeding one could increase these two amino acids, it would make corn a balanced food and feed. Work conducted primarily at Purdue University (Nelson, O. E., 1965) has shown that two genes, opaque-2 and floury-2, when introduced to normal corn significantly increase the percentage of both lysine and tryptophane. Since opaque-2 and floury-2 are single genes, it is relatively easy to introduce them to any corn by appropriate breeding methods. (We are just beginning to convert our elite materials to opaque-2 and floury-2 corn).

3. *Short Plant Stature*: A shorter variety is easier to machine harvest, stands better in the field, and if need be (which is there in most of the low land areas) can be sprayed against various pests rather easily.

4. *Ears with Low Placement on the Stalk, with Tight Husks and Strong Shank*: In the tropics, as in U.S.A., commercial corn production should eventually be completely mechanized. A hybrid having low, uniform placement of ears is easy to machine harvest. Ears with a tight husk can withstand damage by ear worms and fall army worms better than the ones with loose husks. If tight husks are a necessity in a tropical hybrid variety, such a variety will not be adapted to mechanical pickers but will have to be combine harvested, and if it is to be combine harvested, it should possess tough ear shanks (Sehgal and Brown, 1965).

5. *Vigorous Seedling Emergence and Fast Growth*: Any damage to the plant at seedling stage by worms which feed on the young, tender leaves is going to be multiplied many times as the plant grows. A fast, vigorous growing hybrid can offset part of the damage.

6. Resistance to Stalk Breakage

7. Resistance to Lodging

8. Resistance to Various Diseases (Rust and Blight), and Insects (especially Laphygma sps. commonly known as bud worms or fall army worms).

9. Resistance to Chemical Burns by Insecticides and Herbicides.

It hardly seems possible that one can bring together all the above mentioned features in a single variety. This outline, however, can serve as a guide-line factor during the breeding procedures.

INBRED-HYBRID METHOD

In briefest outline, the method involves as a first step, the isolation of inbred lines by selfing or sibbing a few plants in each of the source populations which are open pollinated varieties or races,[1] mass selected populations,[2] synthetics,[3] or composites[4]. After 2 - 3 generations of selfing, the promising inbreds are tested for their combining ability[5] in top crosses with a suitable tester of a broad genetic base which can be a variety or a synthetic. Selfing if continued in the materials which come through the top cross test. During the process of selfing, selection is practiced for desirable agronomic characters both, between and within progenies. Inbreds thus isolated are combined to produce single crosses, each single cross being a product of two inbred lines. The single crosses are yield tested and from the data thus obtained, double cross yield predictions are made. The predicted double crosses are produced by combining single crosses, each double cross being a product of two single crosses.

Several kinds of hybrids are possible depending upon the number and arrangement of inbred lines in crosses. As for example, three-way crosses are produced by crossing a single cross with a third inbred strain. Top crosses are produced by combining an inbred with a suitable tester of a broad genetic base.

Although only four inbred lines are required to produce a double cross hybrid, one can not combine any four inbred lines at random and expect a high yielding hybrid. A great majority of the inbred lines have to be discarded due to their poor

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[1]Race or Variety: Any recognizable population of maize which has become thoroughly stabilized and established in a given area by interbreeding over a period of many generations.

[2]Mass Selected Population: A variety or race of maize subjected to selection for yield and other desirable agronomic characters over many generations.

[3]Composite: The term is usually applied to a mixture produced by hybridizing different varieties or open pollinated populations.

[4]Synthetic: A synthetic is produced by combining many inbred lines (always more than four) which have previously been tested for their combining ability.

[5]Combining Ability: Performance of a strain in crosses with other inbreds or varieties. An inbred is termed as a good general combiner if it results in better than average crosses regardless of the other parents with which it is crossed. A line is referred to as having high specific combining ability if it tends to give superior crosses in combination with certain parents only.

combining ability or some other fault. Furthermore, an inbred must meet certain standards of vigour and productivity before it can merit its use in commercial seed production.

The success of the inbred-hybrid method, as used in the United States, is no doubt familiar to everyone connected with the improvement of corn. We, in the tropics, have a tendency to compare the yield of our hybrids with those of the Corn Belt without sometime stopping to realize the reasons for comparatively low yields which we get here. Firstly, there is more than half a century of intensive research behind the hybrid varieties currently available in the Corn Belt. Secondly, Dr. William L. Brown (Personal Communication) points out that the reason may go back to the rather limited amount of selection for yield that has been practiced over the years in the tropical varieties. Prior to the advent of hybrid corn, the breeders of the open pollinated corn in the Corn Belt put a great deal of effort into selection for yield. These improved high yielding corn varieties served as excellent base populations for the isolation of inbred lines.

The percentage of good inbred lines which we have been able to isolate from a whole array of tropical materials is disappointingly low. The reason probably goes back to the unselected base materials with which we had to start. A brief description of some of the materials used and their relative importance in our programme is given below. A majority of these materials were obtained through the courtesy of Dr. Elmer Johnson of the Rockefeller Foundation, Mexico, to whom our special thanks are due.

Jamaican Corn: Two types of corn, Jamaica Red Corn and Jamaica Selected Yellow (JSY), occur in Jamaica. Both are essentially the same except for the red pericarp colour of the grain in the former. This is probably determined by one of the alleles of the P locus on chromosome 1. Jamaica Selected Yellow was isolated from Jamaica Red Corn in the late 1940's by Mr. L. N. H. Larter of the Ministry of Agriculture and Lands. Both red and yellow types belong to a group of maize called Cuban Flint-Dent, a mixture of the two most productive West Indian races of Maize, Túson and Coastal Tropical Flint.

The tests conducted by Mr. Ed Martin, Agronomist with the Ministry of Agriculture and Lands show that the variety JSY yields reasonably well at higher elevations (1500 ft. to 2500 ft. and over). In low land areas, where most of our interest lies, it yields rather poorly. In addition, the plants grow extremely tall reaching a height of more than 10 ft. with ears placed quite high on the stalk. Being tall, it tends to root lodge. All these characters are objectionable from our stand point. Furthermore, JSY can hardly withstand inbreeding depression. The S_1 lines derived from it, in crosses with derivatives of Coastal Tropical Flint, have shown considerable heterosis. The lines, however, could not be maintained in subsequent generations of inbreeding.

Brown (1960) recognized seven more or less distinct races of maize in the West Indies. These are: (1) Coastal Tropical Flint, (2) Túson, (3) Chandelle, (4) Cuba Flint, (5) Early Caribbean, (6) Haitian Yellow, and (7) St. Croix. We have worked with most of these races or their descendents, and our impressions for some of these are as follows:

Coastal Tropical Flint: It is a widely distributed race in the West Indies as well as in eastern South America. It produces relatively large ears with about 12-14 kernel rows. The grains are deep yellow and flinty. The plants are tall with a single ear which is placed high on the stalk.

In our cultures, this variety has proven to be an excellent breeding material. Inbreds which are good general combiners have been isolated from this variety.

A slightly different version of Coastal Tropical Flint, called Antigua Group 2, obtained from the Rockefeller Foundation, is another excellent breeding material. The inbreds isolated from this have many features, like partial resistance to blight, rust, root lodging, stalk breakage, etc., which are rare among most of the tropical materials.

Cuban Flint: Ears of this race are short and thick with up to 16 kernel rows. The grains are flinty and deep orange yellow in colour. The plants are tall with medium-high placement of the ears. The variety, like JSY, has some good germ plasm in it but can hardly withstand inbreeding depression. After 2-3 generations of selfing, most of the progenies of this race in our cultures, became barren.

Túson: This race, like Coastal Tropical Flint, is very widely distributed in the West Indies. Ears are cylindrical with up to 20 rows of kernels. The kernels are light yellow, slightly dented and with white cap. The cobs are white and thick. Brown (1960) pointed out that this race is one of the most valuable sources of maize germ plasm in the West Indies.

Like Coastal Tropical Flint, this race has proven to be a good source of inbreds. The Túson lines have shown excellent specific combining ability with the ones derived from Coastal Tropical Flint. However, lines of both these races are partially suceptible to blight, and have rather poor roots.

Chandelle: Although this race occurs on many of the West Indian islands it is not as widely distributed as Coastal Tropical Flint or Túson in any one of them. The distinguishing feature of the race is its thin, flexible cob. There are many faults with this race, and with the inbreds isolated from it. Firstly, the cob is thin and fragile; secondly, husks are shorter than the ear; thirdly, poor roots and, fourthly, susceptibility to both rust and blight.

Tuxpeño: The Mexican materials which have entered in our programme mostly represent different composites of the race Tuxpeño. Wellhausen et al. (1952) point out that Tuxpeño is by far one of the most important Mexican races of maize. It is involved in the ancestary of some of the most productive races in Mexico, such as Celaya, Chalqueño and Conico Norteño. It has also been a source germ plasm of the Southern Dents of the United States.

More recently, Drs. Wellhausen, and Johnson have shown that Tuxpeño in crosses with the Caribbean materials, like Antigua Group 2 and Cuba Flint, shows considerable hybrid vigour.

We have been rather disappointed with this variety. When grown in low land areas of Jamaica, it grows extremely tall, bears a short ear placed quite high up on the stalk. Since its good combining ability with other Caribbean materials has been reported therefore we are managing to keep some of its inbred progenies in our cultures. The value of these lines is yet to be fully determined.

ETO Synthetic: This synthetic was developed at Estación Tulio Ospina, Medellín, Colombia, and has been reported to be one of the highest yielding varieties of maize for the low land tropical areas. The Colombian breeders have found it to be one of the excellent sources of inbred lines. Like Tuxpeño, so far we have been somwhat disappointed with this as a source material for inbred lines.

Venezuela I: This variety was developed by Dr. D. C. Langham and his associates in Venezuela. It is reported to have good yield potential, and at one time was recommended for low land areas of both Venezuela and Colombia. The value of this variety as source breeding material is not fully established.

DISCUSSION AND CONCLUSIONS

In spite of the low frequency of inbreds which one gets from the tropical materials, it has been possible to synthesize hybrid varieties which have yielded approximately 100 bushels per acre in small experimental plots. In tests conducted by Caymanas Estates Ltd. on a commercial scale, some of these varieties have given yields of approximately 73 bushels per acre. Furthermore, these varieties are excellently adapted for mechanical harvesting with a combine.

Unlike improved mass selected varieties or synthetics, seed of which can be saved for planting by the farmer without appreciable loss of yield in subsequent generations, a farmer must procure a new supply of seed of the hybrid varieties every season. A hybrid variety is of precious little use if seed of it is not available to the farmer for planting. Brown (1953) states "The success of a hybrid maize programme depends not only on the availability of superior hybrids but equally important is the manner in which hybrids are produced and distributed. The building of a dependable organization of hybrid seed is often a task requiring as much or more effort than the initial breeding".

In Mexico, as for example, the Rockefeller Foundation in collaboration with the Ministry of Agriculture have developed hybrids capable of yielding over 100 bushels per acre but still an insignificant proportion of the total corn acreage in that country is under hybrid corn. Similarly, in Colombia, hybrid varieties have been available for some time but almost negligible acreage is in hybrid corn in this country. Like both, Mexico and Colombia, hybrid varieties are also available in India but farmers still plant local varieties which give them half the yield of what they would get by planting hybrids.

It would be unfortunate if a situation like Mexico, Colombia and India, also develops in the Caribbean. Here, in Jamaica, we have succeeded in developing hybrid varieties and are just beginning to get started with an equally difficult task of production and distribution of hybrid seed.

SUMMARY

The inbred-hybrid breeding system is the most extensively and successfully employed method of corn improvement in the United States. In our corn breeding programme in Jamaica, we are using this method to develop hybrid varieties which are adapted to low land tropical conditions. The selection emphasis is on the following traits:

1. High yield
2. High percentage of amino acids in the grain
3. Short plant stature with relatively low ear height
4. Vigorous seedling emergence and fast growth
5. Resistance to stalk breakage
6. Ears with tight husks and strong shank
7. Resistance to lodging
8. Resistance to various leaf diseases like rust and blight
9. Resistance to chemical burns by herbicides and insecticides.

It is pointed out that it is unfair to compare the yield of tropical hybrid varieties with the Corn Belt hybrid varieties. Firstly, there is more than half a century of intensive research behind the hybrid varieties currently available in the Corn Belt. Secondly, the breeders of the open pollinated corn in the Corn Belt put a great deal of effort into selection for yield prior to the advent of hybrid corn. These improved high yielding corn varieties served as excellent base populations for the isolation of inbred lines. On the other hand, a very limited amount of selection for yield has been practiced in the majority of tropical materials and as a result we have at our disposal rather unselected base materials for inbreeding.

Unlike mass selected varieties or synthetics, seed of which can be saved for planting by the farmer without loss of yield in subsequent generations, a farmer must procure a new supply of seed of the hybrid varieties every season. A hybrid variety is of precious little use if seed of it is not available to farmer for planting. We, in Jamaica, have succeeded in developing hybrid varieties for the low land areas and are just beginning to get started with an equally difficult task of production and distribution of hybrid seed.

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PRACTICE AND PREFERENCE AMONG PIGEON PEA GROWERS IN TRINIDAD

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ABSTRACT

The paper is based on an interview survey of pigeon pea farmers in Trinidad. Its primary purpose was to investigate on behalf of the food crop breeders of the University of the West Indies, the types of pigeon pea plants preferred by farmers in Trinidad. Supplementary questions studied were (a) characteristics of farmers, (b) cropping patterns, and (c) yields and disposal of crop.

INTRODUCTION

For very many years pigeon peas have formed a popular item of the diet in Trinidad. Until World War II local production of the crop was negligible and large quantities were imported from