COCOA BREEDING REVISITED

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INTRODUCTION

In 1987 a small group of geneticists published a review article in the Cocoa Growers' Bulletin, on the state of cocoa breeding around the world (Kennedy et al., 1987). They made a list of general recommendations as to the direction that cocoa breeding and germplasm utilisation should take in the future. Now four years on Dr.A.J.Kennedy, former geneticist at the Cocoa Research Unit, U.W.I, Trinidad and one of the original authors of the 1987 review, and Dr.J.M.Warren, the present geneticist with the CRU in Trinidad, look at the progress made during the intervening years. The future is again contemplated in the light of continuing loss of wild cocoa germplasm.

HISTORICAL BACKGROUND

Germplasm Collection and Conservation

Although obviously the history of cocoa breeding, germplasm collection and conservation has not changed during the past four years, it is necessary to recount some of the major areas of historical importance to compare and contrast them with the way forward.

The first germplasm collections of *Theobroma cacao* were assembled in the early part of this century (*see article earlier in this issue*). These collections were primarily breeders collections based on phenotypic selection of the 'best' locally cultivated trees. Subsequently many of these clonal selections were distributed around the world's cocoa research stations, where they can still be found today. This material appears in the pedigrees of many later breeding programmes. For fuller reviews of the history of cocoa breeding see Pursglove (1968) and Toxopeus (1969). In the 1920's and 1930's witches' broom disease became a serious problem in Trinidad. Dr F.J.Pound, then cocoa geneticist at the Imperial College of Tropical Agriculture, was unable to find sufficient disease resistance among his locally selected (Imperial College Selections or ICS) Trinitario populations. This situation prompted the first significant cocoa collecting expeditions. Pound's collecting trips of 1938 and 1943, therefore, had but a single aim; to search the cocoa populations of the upper Amazon regions of Peru and Ecuador for genotypes resistant to the fungus *Crinipellis perniciosa* (Pound, 1938).

Pound collected wild cocoa from along the Amazon and its tributaries in Peru and also selected material from commercial plantings in Ecuador. It is important to note that these

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upper Amazon accessions were 'selected' and do not represent the spread of natural diversity. Furthermore, the collecting in Peru was restricted almost exclusively to riverbanks since rivers were the only means of transportation. Unfortunately, the precise locations of these collections are now not known and so we cannot return to them to collect any more material.

Following quarantine in Barbados, Pound's collections were transferred to Trinidad and established at Marper Farm. This material has recently been re-established as young trees which are now maintained by the Cocoa Research Unit of the University of the West Indies in the International Cocoa Genebank, Trinidad (ICG,T).

The Chalmers collecting trips 1968 and 1972 (Chalmers, 1972) in Ecuador also collected material with similar economic objectives in mind. The joint Anglo-Colombian expedition (Baker, 1953) however, sampled germplasm using botanical criteria rather than economic ones. The International Cocoa Germplasm Database (End, 1991) sadly reveals that only 51 accessions from this collection remain extant. Plants from these collections are also represented in the ICG,T. These collections are shown in Figure I.

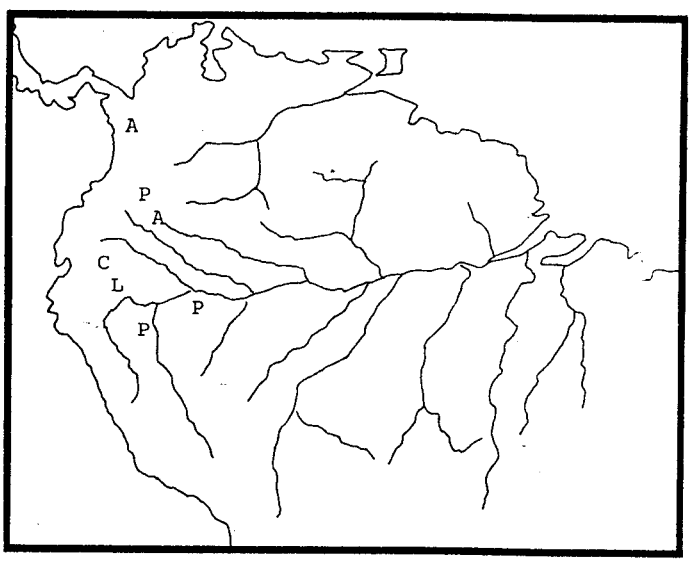

FIGURE 1: A = Anglo-Colombian Expedition
C = Chalmers Collections
L = LCTAP
P = Pound Collections

Crudely stated, the early breeders, when confronted with the problem of requiring genetic resistance to witches broom disease initially searched their own cultivated backyards. On drawing a blank there, they screened the then world genebank for cocoa namely, the wild rain forest populations, and the cultivated areas of Ecuador known to be heavily infested with witches' broom disease.

Arguably, not until the London Cocoa Trade Amazon Project (Allen and Lass, 1983) did anyone attempt to collect cocoa germplasm in a systematic and scientific manner. This expedition had the defined objective of broadening the range of genetic variation available to the breeders. The sampling strategy used was based upon Marshall and Brown (1975) and relied upon collecting 25-50 plants from many populations, rather than intensively sampling a few populations. The objective of this sampling technique was to collect all the alleles present in a population with a frequency of greater than 0.05. Rare alleles with a frequency below 0.05 were considered to be generally uninteresting to breeders. In reality rare alleles can be of great use to breeders, however, there are logistical problems involved in collecting and conserving them.

The IBPGR considers two main factors in determining priority for the collection of material. Firstly, what geographic areas are under-represented in existing collections, and secondly, what areas of variability are under-greatest threat (Williams, 1984). Materials of Criollo origin are considered to be a high priority for conservation because they fall into the second category. The Centro Agronomico Tropical de Investigacion y Ensenanza (CATIE) at Turrialbà in Costa Rica holds a valuable collection of Criollo material which is currently being replicated at the ICG,T in Trinidad. Further collecting efforts for Criollo material would nevertheless be useful.

Breeding

With one or two exceptions notably the TSH programme in Trinidad (see Kennedy et al., 1987) crop improvement in cocoa has relied heavily upon the exploitation of heterosis rather than long term breeding programmes. Inter-population heterosis was first demonstrated in Ghana (Posnette, 1943) and later confirmed in Trinidad (Montserin et al., 1957). This extreme form of hybrid vigour is produced by crossing unrelated/geographically distinct populations of cocoa.

Hybrid seeds currently being released to farmers are often derived from crosses between upper Amazon Forastero types and locally selected clonal material. The lack of any relationship between the parents ensures that the desired heterosis is produced. The upper Amazon parent is commonly obtained from one of the IMC, NA, PA, or SCA populations collected by Pound in Peru. These plants are considered to provide desirable yield, vigour and disease resistant characters.

In Trinidad, the second locally selected parent is usually an ICS accession, and in Costa Rica, United Fruit Company (UF) clones are used. These local parents are believed to provide genes adapted to local conditions and pathotypes. Furthermore, the use of locally selected material as parents maintains regional flavour characteristics.

The segregation that results from crossing two highly heterozygous parent lines is of course massive although this can be masked by the initial heterotic vigour which appears to give uniform progeny. However, improved yield is the aim of the plant breeder rather than vegetative vigour. Commercial plantings of this hybrid cocoa demonstrate a high degree of genetic diversity and phenotypic variation. It is feasible that segregation of polygenic horizontal disease tolerance in this manner may enable virulent pathogens to evolve rapidly. This may occur, since in the F1 cocoa the genes for disease tolerance are diluted throughout the population. Pathogens may, therefore, evolve around each separate gene in a polygenic system in isolation. Inversely, quantitative traits, such as yield, cannot be improved by the mixing of desirable genes from several accessions when only a single generation is used in crop improvement. As a consequence of this simple crop improvement procedure, virtually all commercially grown cocoa can trace its ancestry back to a wild rain forest tree in only one or two generations. This is a fairly unusual situation for any crop species.

THE PRESENT

Germplasm Collections and Quarantine

The situation in the two germplasm collections recognized by the IBPGR (in Costa Rica and Trinidad) has not altered significantly since 1987. In Costa Rica, the collection is being re-established as young plants following problems with mis-identification of the existing accessions. The replanted collection is being arranged by geographic origin of the material. In Trinidad, all Pound's upper Amazon accessions have been regenerated from the original old trees held at the Marper Farm germplasm collection and on other private estates. The ICG,T is now located solely at the La Reunion site and now contains about 2000 accessions. Material continues to move into Trinidad, via quarantine in Barbados, from small collections in Central and South America.

The free flow of cocoa germplasm around the world is still restricted by the linited number of quarantine stations. The US Department of Agriculture centre at Miani remains the major effective recognized service. The BCCCA/Reading University Quarantine Station now also provides an alternative temperate quarantine facility. There are also plans to expand the small facility maintained by IRCC at Montpellier.

Questions should perhaps be raised about the expression of disease symptoms in pot grown cocoa in quarantine. Little is known at present about the expression of cocoa diseases under these conditions. Immunological tests may be required to determine whether non-virulent viruses are present in quarantined material. Clearly there is a case for further research to be carried out on the expression of disease symptoms in non-stressed young cocoa of various genotypes. There is also a need for clearly defined and internationally agreed upon guidelines regarding the operations of plant quarantine stations. At present there is no obligation upon stations to notify clients of suspected problems should any arise.

The Barbados quarantine station of the CRU in Trinidad is now operating efficiently following problems with water stressing although space is limited.

Biotechnology

Since 1987 there have been no major breakthroughs to report in cocoa biotechnology. The technical problems involved in regenerating cocoa plants from callus tissue remain unsolved. Thus the 'genetic engineering revolution' has not yet started for cocoa.

The development of successful micropropagation techniques is still expected to have a major impact on the movement of cocoa germplasm and management of genebanks, as it has in other crops. Given the current interest and research activity this breakthrough must surely be only a matter of time.

THE FUTURE

Germplasm Collecting and Collections

The future strategy of germplasm collection and subsequent management is influenced by the fact that neither pathogens or agronomic practices stand still. It is impossible to predict what new disease might be just around the corner or what cultivar will best suit future management practices. For these reasons, germplasm collections must never reject material simply because it is of no current economic interest. After all, the reject made today may be the wonder cultivar for high density planting which is needed tomorrow.

Genes which provide resistance to diseases which have not yet evolved onto cocoa will be present in natural populations at very low frequencies. This situation is analogous to the frequency of metal tolerance genes in populations growing in non-toxic sites, or herbicide tolerance genes in weeds before the application of herbicides. Furthermore, if disease resistance is polygenic then the frequency of individuals within a population which are resistant will be very low indeed.

The frequency of individuals in a population homozygous at five loci with individual allele frequency of 0.05 is:

$$f = (0.05)^{2x5} \qquad \text{approximately 1 in } 10^{13}$$

After Hallauer (1985)

As we have seen, the wild populations of *T.cacao* have been used by breeders in the past as a germplasm collection. These wild populations may or may not contain such desirable rare genotypes. The continued loss of cocoa germplasm from the wild and the simple economics involved in collecting, means that it now makes sense for breeders to obtain desirable genes from the two internationally recognized germplasm collections.

Sadly, although these collections contain a great diversity of material, much of it was either selected by plant breeders from the wild or represents the best of the locally cultivated material. Thus these collections cannot be said to contain the full range of natural diversity that may be required in the future. This situation will be confronted by both the proposed BCCCA/INIAA planned collecting programmes in Peru, by the CRU's proposed collecting trips in Trinidad and neighbouring islands and by other collecting programmes. These programmes will have the objective of broadening the genetic base of collected cocoa germplasm. This can only be achieved by using systematic and scientific criteria for selection of material collected, rather than economic ones.

Breeding

The breeding objectives proposed in 1987 still remain as desirable today. Unlike the germplasm collections which must hold material for unknown eventualities, breeders should have clearly defined goals for the future. As was pointed out in the 1987 article little attention has really been paid to yield improvement in cocoa. There is no point in a cultivar being highly disease resistant if it is low yielding. There is a need to identify the heritable components of yield and combine them via mass selection techniques. At some point the current reliance on heterosis for crop improvement must be abandoned in favour of longer term recurrent selection methods.

It is a sad reflection on the present state of cocoa breeding that there has been no significant progress to report in crop improvement since 1987. Although we have stressed a possible limitation of existing cocoa germplasm collections, there is more than adequate genetic variability already available to breeders to produce vast improvements in yield. It is the job of the local breeder to address this problem and utilise the considerable array of genetic resources which is already available.

The existence of genotype/environment interactions demands that breeding programmes be carried out locally to produce varieties adapted to local conditions. As was stressed in the 1987 article, evaluation of cultivars should be the responsibility of the local breeder not the manager of the germplasm collection. It is hoped, however, that a database catalogue of heritable variation held in the two germplasm collections will assist breeders in choosing which material to request from these centres. This information should be available in the not too distant future.

REFERENCES

Allen, J.B. and Lass, R.A. (1983) London Cocoa Trade Amazon Project. Final Report Phase I. Cocoa Growers' Bull., 34.

Baker, R.E.D. (1953) Anglo-Colombian cocoa collecting expedition. Archives of Cocoa Research. Vol 1. 127-154.