WORKSHOP CONCLUSIONS AND RECOMMENDATIONS

Economic losses

• There is a need to collect more reliable data on real losses incurred due to cocoa diseases and pests. Such information would guide decision makers and researchers in their search for more efficient methods to control these important production constraints.

Phytopathological aspects related to resistance breeding

• The response of cocoa to its pathogens includes primarily partial, polygenic resistance; it can be measured and exploited by breeders using current techniques including "Components Analysis".
• Early tests for resistance to cocoa diseases have often shown low representativeness, unproven predictiveness and unspecified differential capacity. Nonetheless, the use of such tests, possibly combined with molecular analyses, is imperative to ameliorate progress in resistance breeding.
• International consensus on test protocols and on pre-breeding strategies is required and INGENIC should facilitate discussions leading to such consensus.
• Due to the high variability of pathogens, the use of more than one resistance source in the development of new commercial varieties is recommended.
Information on resistance levels observed in the field and in resistance tests should be made available through the International Cocoa Germplasm Database.

Resistance to *Phytophthora* pod rot

• Resistance evaluation in West Africa, Latin America, the Caribbean and Asia has resulted in the identification of promising clones with increased resistance and/or escape to the disease. In Brazil, some clones were identified with resistance to more than one *Phytophthora* species.
• The degree of field attack of individual trees is influenced not only by their intrinsic resistance, but also by the level of attack of neighbouring trees, by pod load and by escape phenomena.
• Results from Cameroon, Trinidad and Côte d'Ivoire indicate that the leaf inoculation test is promising as an early screening method for identification of resistance of clones or progenies. Correlations with field resistance were established in Côte d'Ivoire, Cameroon and Trinidad by applying standardised test procedures. More research is required to identify the influence of environment and leaf age on test results.
• Ranking of the general combining ability of a number of genotypes for field disease incidence in Cameroon, Togo and Côte d'Ivoire suggests that field reactions are consistent between countries, despite the different *Phytophthora* species involved. This finding is in line with absence of strong interactions between fungal isolates and cocoa genotypes observed in leaf inoculation tests.
• In Trinidad, a rapid resistance evaluation method was developed involving spray inoculation of detached pods. This test seems promising for application in a pre-breeding programme, such as that already initiated by CRU.
• Test methods differ between countries. More data are being collected in laboratories than in the field and should be compared with field results. Standardization is important to confirm the representativeness of different resistance tests and their use in international collaborative studies.
• Results from Costa Rica and Côte d'Ivoire indicate that significant links between resistance to black pod and molecular markers can be established. QTL studies are being continued in collaborative research programmes.

Resistance to witches' broom disease

• Resistance reactions, evaluated by broom growth, broom death and basidiocarp production can be used to identify useful selections in collections. Isolates differed greatly in aggressiveness, but ranking order remained the same indicating that resistance against one fungal isolate might also be effective in relation to other isolates.
• It is recommended to continue the work related to challenging of promising cocoa genotypes with different fungal isolates outside cocoa-producing countries.
• The Workshop stressed the need for further studies on the reliability of early screening tests for witches' broom disease that are adapted to the breeders' needs of rapid evaluation of clones and progenies. Screening for resistance using cocoa seedlings, as practised in Brazil and Ecuador, has shown a correlation with field resistance and permitted the identification of promising new materials. Further work on alternative methods for identification of individual plant resistance and of clones is to be encouraged.
• Resistance evaluations of collections in Brazil revealed higher resistance in Upper Amazon material than in Lower Amazon material. Other sources of resistance than the well-known Scavina clones were identified in collections in Brazil as well as other countries (Peru, Trinidad, Ecuador). Furthermore, more resistant material was identified in Ecuador in a national survey carried out in farmers fields. These reports suggest that breeders can rely on several different sources of resistance to this disease.
• International collaboration is needed to exchange different sources of resistance, so as to facilitate the accumulation of resistance genes.

Resistance to Vascular Streak Dieback (VSD)

• The *in vitro* dual culture laboratory method was found reliable and could be used for rapid screening of clones or individual trees within progenies as well as for research into the host-pathogen interaction and their application by cocoa breeders.
• Inheritance studies indicated that resistance to VSD is heritable, polygenic and additive. Accumulation of VSD resistance genes is emphasized, together with resistance to *Phytophthora* pod rot.
• International collaboration is required for exchange of material, standardization of resistance test methods and their application in breeding programmes.

Other diseases

• Exchange of clones with resistance to *Moniliophthora* is recommended along with implementation of tests under field conditions. Recent evaluation of collections in Peru indicates the great severity of this disease, but variation in disease incidence between entries was observed. More attention is urgently needed to further develop resistance tests and find additional sources of resistance to this spreading disease.
• Mutation breeding appears to have promise in creating material with resistance to Cocoa Swollen Shoot Virus (CSSV) as well as with variation for other useful traits.
• Resistance to *Ceratocystis* was identified in Venezuela, and this has been incorporated into commercial varieties.

Breeding

• Advances in cocoa breeding are best achieved by (reciprocal) recurrent selection schemes, such as those adopted recently in a number of countries, as such methods can take advantage of the predominantly additive gene action observed for most selection traits in cocoa, and will increase chances of detecting transgressive types. Resistance breeding is to be integrated into such programmes that should simultaneously take into consideration other selection criteria such as yield, bean size, uniform plant type and quality.
• Quick progress can be obtained by fixation of interesting genotypes by clonal selection. Improved methods of vegetative propagation, including micropropagation, have therefore a role to play in the rapid distribution of clones resistant to destructive cocoa diseases.

• Recombination of resistance genes of different origins is expected to allow quick selection progress as it is likely that resistance genes with relatively large effects on partial resistance can be found and efficiently accumulated.
• Good field data obtained under local conditions are the best basis for the start of any breeding effort for increased resistance, but pre-selection tests are essential in obtaining quick progress.
• Consideration should be given to re-designing the cocoa tree architecture in order to not only improve photosynthetic efficiency and harvest index, but, concurrently, to increase the effectiveness of available partial resistance to cocoa diseases.
• Such programmes need breeders who combine expertise in genetics with general knowledge in agronomy and crop protection. In addition, effective team work involving pathologists, entomologists etc., competent field staff for excellent field trial execution, and last but not least, adequate funding are essential.
• Global projects related to germplasm utilization and conservation deserve international support from producer and consumer agencies. Any pre-breeding programme at germplasm centres should be endorsed by national cocoa breeders, who are in the best position to decide on the selection criteria and material to be used in such a programme.