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Can genetic resources cope with global warming?

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The prospect of climatic change has become an important environmental issue worldwide. The increase in atmospheric carbon dioxide (CO_2) levels in recent decades is now recognized to be largely a consequence of the combustion of fossil fuels, continuing deforestation and increasing methane emissions from growing numbers of ruminant livestock and the expanding area of rice paddies. The greenhouse effect is now firmly on the political agenda of most political parties in the UK, and most likely elsewhere in the developed world.

Environmentalist Russell E. Train (Board Chairman of the World Wide Fund for Nature) has recently been reported as presenting strong arguments to the US Congress about the need for global action on the environment, emphasizing that the international political climate is now conducive to this. A list of such indicators includes the communiqué from the Toronto Economic Summit in 1988, significant environmental reforms instituted by the World Bank, the European Community's decision to eliminate chlorofluorocarbons (CFCs) by the year 2000 and the US pledge to accelerate their phase-out. At the same time, leading environmentalists press for international programmes to preserve the earth's biodiversity, to reverse deforestation and to act on global environmental issues. An illustration of this is the International Biodiversity Convention currently under development by the United Nations Environment Programme (UNEP) and the International Union for the Conservation of Nature and Natural Resources (IUCN) (Anon., 1989).

Even if, under the most optimistic scenario, international controls on emissions of 'greenhouse gases' were implemented within the next 20 years, the time-lag on warming to which the earth is already committed (see Rowntree, this volume) together with the effects of future emissions mean that, in all likelihood, we will have to cope with the greenhouse effect, and its consequences, for agriculture and genetic resources. If this premise is accepted, it indicates that planning must begin *now* to confront a 'worst case' scenario resulting from climatic change. This is a point of view endorsed by the report to the Commonwealth Conference in Malaysia in October 1989, which concluded that the magnitude of projected climate changes demands the immediate evaluation of technical and policy options.

At a meeting held in the USA in May 1989, sponsored by the US National Academy of Sciences, the Smithsonian Institute, the American Association for the Advancement of Science and Sigma Xi (the Scientific Research Society), the effect of global climate change on food supplies was discussed. Many participants were pessimistic concerning future developments, and about the fear that food supplies will be threatened by climate change. Furthermore, they feared that it would be unlikely that we could develop new crop strains quickly enough to keep pace with rapid changes in environmental conditions.

This pessimism was not shared by all. Theodore L. Huller, Chancellor of the University of California, Davis, and Chairman of the US National Research Council/National Academy of Sciences Board on Agriculture, presented a different scenario, namely that climate change is always present for agriculture, and that while predicted changes will increase stress on agriculture, agricultural research is capable of adapting to these problems, as it had done so to similar ones in the past. Germplasm is one of the important tools for the plant breeder to adapt to new conditions, and furthermore there are new crops which can be exploited.

This optimism was shared by Norwegian Prime Minister Gro Harlem Brundtland, who stated that 'the benefits of plant breeding and plant varieties with greater resistance and more rapid growth potential have been, and will continue to be, immense'. Given the successes of breeding programmes over the past 30 years, this view seems reasonable. However, if agricultural scientists, breeders and germplasm specialists are to provide the framework for research and the development of new crop varieties, then it is clear that research funding policies for the 'greenhouse effect' must change. Germplasm evaluation must be given a higher priority. Germplasm specialists have applied considerable effort to ensure that valuable genetic resources are now conserved in genebanks worldwide. In order to utilize this material efficiently, we must find out what useful genes it contains to assist in the development of crop varieties more appropriate for the altered climates we should anticipate in the future.

It is important that these efforts should co-ordinate with current programmes of crop development, which themselves incorporate worrying contradictions (Cleveland & Soleri, 1989). To illustrate, some would argue that the New Green Revolution is now based upon changes in crop breeding goals to include greater diversity through increases in varietal heterozygosity, the number of environments for which varieties are developed including those which are more marginal, cropping systems diversity through production in multiple cropping and agro-forestry systems, and management diversity by decreasing the production inputs required (Hazell, 1986). Some, however, criticize this strategy because maintaining and increasing yields and production remain major goals, and it is suggested that an alternative New Green Revolution with more promise for addressing the goals of poverty and hunger alleviation should really begin with the diversity which is present in locally adapted production strategies based on landraces (Cleveland & Soleri, 1989).

Regardless of the efficacy of such arguments about the desirable form of any New Green Revolution, it would seem clear that any current or future Green Revolution must take account of global climatic change, and will have to take advantage of the world's genetic resources in a greater way than ever before.

The workshop held at the University of Birmingham, UK, which was the basis for this book, was a contribution to the debate over the future and importance of plant genetic resources in ensuring that agriculture can cope with climate change and maintain food supplies at sufficient levels. The following conclusions emerged from discussions at the workshop.

1. Significant changes of climate are likely to occur over the next 50 years and, although there is uncertainty about the magnitude and rate of these changes, research and management of genetic resources should take account of them in terms of collection, conservation and utilization strategies.

2. Efforts should be made to improve the accuracy of climate change predictions, so that biologists have better information on which to base policy decisions. In the meantime, efforts should be made to relate climate models with global vegetation patterns. The mapping of such relationships will be useful to demonstrate the possible vegetation changes due to climate.

3. Consideration should be given to vegetation (e.g. mangroves) most at risk from rises in sea level as a result of global warming.

4. The preservation of ecosystems, and a diversity of habitats and topography, is important if plant species are to retain flexibility to respond to climate changes. Nature reserves should be designed and established to allow for future colonization. This is an important aspect discussed in detail by Peters and Darling (1985) and Peters (1988).

5. Developed economies in temperate countries are probably better able than less-developed economies in the tropics to cope with the effects of climate changes. Priority should be given to research in the dry tropical areas, although research being planned or implemented in the temperate regions might serve as models for research to be carried out in the tropical areas.

6. It is important that the characterization of germplasm should be undertaken in order to identify that which will be better adapted in the future altered climates. In terms of both wild and cultivated species, a better understanding of ecogeographic variation is needed. In this context, it is also necessary to evaluate the critical tolerance ranges of crops with respect to climate, estimating these according to the crop varieties grown in a particular regional environment during the investigation period as a preliminary to evaluating the changes in climatic tolerances required to accommodate climatic change.

7. Screening for drought tolerance, raised temperatures and salinity should be increased. Agriculture and plant breeding are not making adequate progress in the arid areas of the topics, particularly as little is known about re-translocation of photosynthetic products in crop plants growing under stress. Account should also be taken of quality parameters, so that these do not decline as a result of adaptation to changing environmental conditions.

8. Further physiological research is needed on the combined 'direct' effects of CO_2 and the effects in altered climates on plant growth. At present it is not clear how far enhanced photosynthetic rate and water use efficiency in C_3 crops as a result of elevated CO_2 will compensate for some of the negative effects of higher temperatures and reduced water availability.

9. Useful information for plant breeders can be obtained from plant growth simulation models. These can be used to simulate plant growth and development under a range of environmental and management conditions (specified as input variables such as climate, soils, CO_2 concentration, sowing date and plant density). Altering these inputs according to projections of future climatic change can, for instance, provide information for breeders on the likely environmental effects on fundamental plant processes that will need to be accommodated in crop breeding strategies. It is important, however, that simulation models are sustained by experimentation under controlled conditions, or in a number of different environments in which the performance of actual plants can be monitored.

10. Improved understanding is needed of the effects of changes of climate, not only directly on weather and its implications for plant growth but also on other physical processes, for example, on rates of salinization of soils, on leaching of soil nutrients, and on pests and diseases and their vectors. These are parts of a nexus of environmental changes which should be considered by plant breeders.

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