Global warming: the case for European cooperation for germplasm conservation and use

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Summary

Two premises underpin the ideas presented in this paper. First, CO_2 emissions will result in climatic change, as a result of global warming, although the rate and magnitude of change cannot be predicted with certainty. Secondly, germplasm evaluation is an activity which is an integral component of genetic resources conservation and utilization programmes. Global warming will have important consequences for two aspects of genetic conservation, namely *in situ* conservation and regeneration of germplasm. *In situ* conservation of wild species based on present eco-geographical distribution patterns will become an unrealistic strategy if climate belts shift northwards as has been predicted from the various general circulation models (GCMs). The regeneration of germplasm must be given greater consideration under global warming, particularly for outbreeding species, since changed environmental conditions might lead to differential fertility between parents. Steps must be taken to reduce the loss of genetic variability. Global warming will bring about additional stresses in the agricultural environment which must be faced by plant breeders. Since such warming will transcend national boundaries, there are sound reasons for closer collaboration between germplasm programmes across Europe via crop networks. Arguments will be presented for continent-wide germplasm trials, to obtain estimates of genotype x environment interaction. In Europe, north to south and west to east, there is a wide range of climatic conditions at present, particularly in terms of temperature gradients which approximate to conditions predicted to occur under a future $2 \times CO_2$ climate. Barley will be used as an example, since there are many collections of this crop throughout Europe, many of which are already linked through the European Barley Database.

Introduction

It is my intention in this paper to raise a number of issues related to the conservation and utilization of plant genetic resources which I hope will stimulate discussion amongst plant breeders and genetic conservationists. First of all I shall present a brief discussion of some of the widely accepted predictions of climate change in Europe which will result from global warming caused by the so-called 'Greenhouse Effect'. I shall then go on to discuss two aspects of germplasm conservation, namely *in situ* conservation and regeneration strategies which might be affected directly by global warming. Finally, I shall evaluate some ways in which germplasm specialists and plant breeders might respond to the threat of global warming, and which are linked to the theme of the EUCARPIA/IBPGR symposium on crop networks.

Global warming and climatic change

The first question we need to ask is whether global warming is something about which we should actually worry? Certainly there has been a lively debate in the scientific and popular press, for and against the likelihood of global warming. Whilst this controversy will continue unabated, a consensus does appear to be emerging amongst scientists that global warming is a phenomenon which mankind must face over the next 40-70 years. This certainly was the message which came from the Second World Climate Conference held in Geneva at the end of October 1990.

Causes of global warming Global warming will be caused by an increase in atmospheric concentrations of radioactively active gases, which will continue to increase unless measures are taken to curb emissions. The greenhouse gas which has been changed most by man in terms of its potential effect on climate is CO_2. The increase in CO_2 starting in the eighteenth century has been partly due to man's effect on the earth's vegetation, notably deforestation, and increasingly to fossil fuel burning. Other greenhouse gases include methane (CH_4) and CFCs. Contributions of CO_2, CH_4 and CFCs to the greenhouse effect are estimated at about 60, 30 and 10% respectively (Rowntree 1990).

At the present time there are sound theoretical reasons, according to Rowntree (1990) for anticipating a change in climate larger than any the world has experienced since the end of the last Ice Age, over 10,000 years ago. Temperatures are predicted to rise to higher levels than any experienced during the last several hundred thousand years. Most estimates of future climate change are derived from results of experiments with general circulation models (GCMs) because these at the present represent the best means of estimating the climate of the future. One broad type of scenario is that derived from 2 x CO_2 equilibrium experiments, that is a situation under which there is an increase in greenhouse gases equivalent to a doubling of atmospheric CO_2. This doubling has been estimated at 460 ppm by about 2030, and represents an approximate 60% increase over pre-industrial levels (IPCC 1990).

Critical uncertainties One of the principal problems with using GCMs, is that although they agree in the general climatic trends which can be anticipated, the rate and magnitude of changes cannot be predicted yet with any certainty, and confidence in any one prediction of changes at the regional scale, particularly of rainfall, must be regarded as low. Despite these constraints, should we ignore the probability of climatic change, as some undoubtedly will suggest, or should we look at some of the predicted changes and then evaluate any responses? I favour this second approach.

Predictions of the effects of future climatic change range from wild exaggerations in terms of sea level rises, for instance, to more conservative estimates of temperature increases. One recent publication gives a reasoned account of the probable effects of climate change on world agriculture (Parry 1990). Under one 2 x CO_2 scenario, mean temperatures in the mid-latitudes (30-60°N and S) are estimated to rise by 2-4°C, but smaller rises of 1.8°C are predicted for low latitude regions, although semi-arid regions may warm more. There are great uncertainties about future changes in precipitation. In the higher northern mid-latitudes (45-60°N) an increase of 5% in summer and as much as 15% in winter could occur. An increase in potential evapo-transpiration can be expected in the order of at least 5% per degree of warming (IPCC 1990).

Climatic change in Europe How will such climatic changes affect Europe? In broad terms, the northern countries of Scandinavia are expected to gain from global warming more than any other region of the world. In Finland, for example, the equilibrium 2 x CO_2 climate is predicted to be wetter than present and about 4°C warmer. In northwest Europe, conditions would allow the extension northwards by perhaps several hundred km of crops which are barely profitable at present, such as maize and sunflowers (Parry *et al.* 1989).

In the Mediterranean region quite substantial decreases in productive potential could occur if the GCMs are correct in predicting decreases in soil moisture in the summer, and possibly also in the winter months. Under the U.K. Meteorological Office BMO 2 x CO_2 climate, with a 4°C warming and with annual rainfall reduced by >10%, biomass potential in Italy and Greece is projected to decrease by 5% and 36%, respectively (Santer 1985). There may therefore be a striking contrast between northern and southern Europe in terms of biomass potential, suggesting a northward shift of agricultural potential.

In the Alps, a temperature increase of only 1°C would raise climatic limits to cultivation by about 150 m (Balteanu *et al.* 1987), and should an increase of 4°C be reached, then climatic zones in the Alps might be raised by 450-650 m, similar to those which currently exist in the Pyrenees which lie 300 km south of the Alps.

C_3 and C_4 plants It is also important to consider the different responses of C_3 and C_4 plants to enhanced CO_2 levels. For C_3 plants, a doubling of ambient CO_2 on productivity has been shown to be beneficial, through the so-called 'fertilizing effect' of CO_2, and a 10-50% increase in dry matter can be expected under some circumstances (IPCC 1990). However, interactions with other environmental conditions are critical in determining the net effect of increased CO_2 (Morison 1988). Future warming clearly depends on the warming we are already 'committed' to and on future trends in greenhouse gas concentrations.

In situ conservation

It is clear that *in situ* conservation has received greater attention in recent times, but such strategies cannot be applied to crop plants with any degree of security for their long-term conservation. *In situ* conservation methods are those that maintain germplasm in wild populations by paying due regard to the natural ecosystems in which the conserved populations are a part (Ingram & Williams 1984). Since species are preserved in their natural habitats, they have the potential for continued evolution. The important question to ask, however, is 'To what extent is *in situ* conservation a viable component of a genetic resources programme under global warming?'. Conservation of ecosystems does not ensure continuing adaptive change unless the genetic base of the species is sufficiently wide (Frankel 1970). Williams (1990) has raised a number of issues related to climatic change and conservation strategies. Wild species survive in the field because they are adapted to particular environments. Some have a much wider environmental tolerance. Clearly the ability to survive will depend upon the potential of plant populations to adapt to environmental change. Yet the time-frame envisaged for a doubling of atmospheric CO_2, and consequent warming is only about 40-60 years, clearly a very short time span for such adaptation to occur.

The example of forest tree conservation If *in situ* conservation of annual species is problematical, what are the implications for long-lived perennials, such as forest trees? There are some data of the effect by man on forest tree populations and as Hattemer and Gregorius (1990) have pointed out, man-made atmospheric change adds a new environmental factor to those already exerting an influence on the evolution of populations. Forest geneticists in Germany have studied the effect of gaseous pollutants on conifer clones. Individual adult trees in environmentally stressed stands were damaged to different extents, and the variation between tolerant and susceptible trees could be attributed to genetic causes. By analogy it should also be possible to use these data to predict what might happen to forest trees and other species populations under climatic change.

Hattemer and Gregorius (1990) have recognized three different goals which may be achieved by conserving gene resources:

- preserving the potential of desired trait expressions;
- preserving genetic adaptability;
- preserving unrecognized genetic variation.

Whilst these points apply broadly to all genetic conservation strategies, they are particularly relevant to consider in terms of *in situ* conservation stands for forest trees. Trait expressions are unique to present environmental conditions, and an assessment of economic value relates only to current market situations. In terms of genetic adaptability, this depends on the range of diversity within populations. If we cannot predict accurately what future climatic conditions will be, then this goal of genetic conservation becomes more important. The third point disregards actual or potential use in favour of conservation of the widest range of genetic variation, without taking into consideration either present economic value or adaptation to past environmental change. *In situ* conservation is a dynamic process (Guldager 1975). It can be argued for long-lived perennials such as trees, which will be expressed to heterogeneous environments both in space and time, that populations which are conserved by static methods would display severe lack of adaptation when exposed to changed environmental conditions, even if static methods were completely feasible. Consequently, this indicates that dynamic conservation aimed at the preservation of adaptability should be given priority under global warming (Gregorius 1989).

The sort of environmental changes which are expected as a result of global warming will be selective. Some changes like increased CO_2 will be advantageous in one respect, because of the fertilizing effect of increased atmospheric CO_2, but this is expected to reduce foliar nitrogen content. It is anticipated that this will alter the dynamics of host-parasite relationships, as pests consume greater quantities of leaf material to obtain the same nutritive value as a smaller quantity at current CO_2 levels (Hattemer & Gregorius 1990).

The adaptability of species populations The adaptability of plant populations to colonize new areas must also be evaluated when considering *in situ* conservation strategies. Peters and Darling (1985) and Peters (1988) have outlined some of the consequences of the design and implementation of *in situ* reserves under a changing climate. It is likely that the present ecogeographical ranges of some species will be altered (Grime 1990). Species which have a narrow distribution are under greater threat than those which are more widely distributed. Furthermore, the establishment of *in situ* reserves today at one location may become inviable after climate belts have shifted. In addition, whether or not plant species have the capacity to migrate from refuge sites, there remains the intractable problem that migration will need to take place over a short period of time. What's more, mankind has created what might be considered as a desert over which colonization will be extremely difficult, since natural ecosystems have been transformed to agriculture, or landscapes have been covered with concrete and tarmac. Under these circumstances plant migration will be slow and hazardous (Peters 1988).

It is important therefore that due consideration be given to these problems across Europe, and that those concerned with either natural ecosystem preservation or genetic conservation begin a dialogue to evaluate what possible responses to global warming might be, and how cooperation can be established.

Regeneration of germplasm

In terms of germplasm regeneration strategies there are just a few points relevant to consider in terms of global warming. Gale and Lawrence (1984) have evaluated the decay of variability, particularly in outbreeding species over successive generations of a genetic conservation programme. Since genetic conservation is normally achieved with relatively small populations, the chances for genetic erosion to occur are quite high unless steps are taken to avoid this. Gale and Lawrence (1984) point out that a population under conservation may lose variability owing to natural selection, which is likely to lead to a deterioration in the economic qualities of a crop. Natural selection will be minimized if plants are raised under optimum conditions, and if the genetic contribution of different parent plants to the next generation is made equal.

Environmental change due to global warming might increase the relative pressure on particular populations. Differential fertility between parents during regeneration brought about by lack of adaptation will increase the probability of some loss of variability over time. Whether regenerating material under present climatic conditions or under a future 2 x CO_2 climate, the arguments for avoiding open pollination in outbreeding species remain the same, and steps should be taken to maximize the maintenance of variability. It may be necessary to give greater consideration to careful cross pollination when regenerating seed lots than perhaps is economically feasible at present.

In Europe the consequences of climatic change for germplasm conservation *ex situ* are perhaps less immediate than elsewhere in the world, where changes in precipitation patterns for example would seriously limit the field multiplication of some crops, at some gene bank sites. Nevertheless, germplasm collection curators should be aware of the implications of climatic change for this aspect of *ex situ* germplasm conservation.

Evaluation and utilization of plant genetic resources

Faced with the threat of climatic change how should plant breeders and germplasm specialists respond? Should we, as some have suggested bury our heads in the sand so to speak and ignore the issue, or should we examine the strategic options for a worst case scenario?

Responses to climatic change

There are several questions which should be asked. First, is it possible to breed for climatic change? Assuming that this is feasible, do plant breeders already have sufficient genetic variation to fulfil this breeding objective, and what will be the role and importance of plant genetic resources collections? Finally, what sort of characters should be studied, and in what ways can germplasm be identified that will increase adaptation to new environments?

Analogue regions

One response to climatic change has been described by Parry and Carter (1990) as the identification of 'analogue regions', which have a present-day climate that is analogous to the future climate estimated for a study area. Analogue regions could be effective in illustrating the magnitude of climatic change within a region in terms of the present day differences between regions. Furthermore, it is suggested that present day farming types in analogue regions are a useful indicator of the adaptive strategies likely to be required to retune agriculture to altered climatic resources. There are of course several difficulties with this approach. In terms of the use of germplasm and crop improvement, one of the most important general difficulties with respect to crop growth is the variation of daylength with latitude. Crop varieties at high latitudes are bred for short growing seasons with high photoperiods, so although the shift of crop varieties from current lower warmer latitudes to higher latitudes would make sense from a climatic point of view, these varieties may not be adapted to the long daylengths.

Utilization of relevant genetic resources could be simplified if it can be assumed that the future climates of a region have previously occurred elsewhere. Even in temperate regions many of the new climates met under greenhouse warming will not be copies of present-day climates in warmer regions (Rowntree 1990). This is because the solar radiation regime and often the rainfall will continue to be controlled largely by latitude. Thus climates will be created which have no precedent. For example, winter temperatures similar to those of northern Spain will occur in a more northern land where the days are shorter than previously observed with such temperatures. Similarly, northern continents will experience summer warmth with longer days than previously were associated with such temperatures.

Screening germplasm for temperature and photoperiod sensitivity Richard Ellis and his colleagues from the Plant Environment Laboratory at the University of Reading have conducted many experiments aimed at studying the relations between temperature and crop development. Gene expression for many characters is quantitative. The results of research with diverse genotypes in several contrasting crops have shown that although the actions of temperature and photoperiod ultimately result in the same event, namely flowering, responses to these factors are independent. Ellis *et al*. (1990) therefore suggest that these factors could be selected for separately, and that it would be prudent to anticipate these problems in screening germplasm collections in crop improvement strategies which need to have more distant time horizons than current breeding programmes.

How might this be achieved? Germplasm response to an elevated CO_2 atmosphere can only be carried out under controlled environment conditions, which are probably beyond the scope of most germplasm programmes. However, throughout Europe, from north to south, from Scandinavia to North Africa and west to east, from Ireland to the Soviet Union, there already exists a wide range of climates, many of which have the temperature characteristics similar to predicted future climates. Obviously it is necessary to ignore the actual direct effect of elevated CO_2 concentrations, which are assumed to be positive, and the combination of higher temperatures with longer photoperiods.

A European network of field trials There is one way perhaps in which collaboration between germplasm collections might be initiated, through the establishment of regional field trials across Europe to evaluate the magnitude of genotype x environment interactions. In this way it should be possible to evaluate germplasm for both temperature sensitivity and photoperiod response, and at the same time test the validity of analogue regions, for which there has been no experimental work.

Barley would seem to be an excellent candidate crop as a model for such collaboration. As an autogamous diploid, it can be expected to be weakly buffered genetically such that genotypic responses to environment should be more easily detected. Secondly, the concept of a crop network for barley is quite well established, and a core collection for this crop is being formulated. Furthermore, a European barley database has already been compiled (Knüpffer 1988).

In the most recent IBPGR directory of cereal germplasm collections, Bettencourt and Konopka (1990) list 68 institutes which maintain collections of barley in Europe and North Africa. I believe that these collections should begin to collaborate to evaluate barley germplasm systematically in a network of field trials in which both improved varieties and landraces from each collection would be included, and trialed extensively throughout Europe to obtain estimates of G x E. Trials such as these are already routine for the international centres such as CIMMYT and IRRI, with their international nurseries for wheat and maize, and rice respectively. The International Potato Center undertook some research some years ago with scientists from Agriculture Canada, based on field trials of the same varieties in different countries, in an attempt to predict the performance of different potato varieties under different environmental regimes (Young & Tai 1983).

Plant breeders in Europe have perhaps never been faced before with a challenge such as climatic change which will require a response transcending national boundaries. Through the establishment of crop networks, it should be possible to develop different research strategies, in which germplasm evaluation must be an important component, to generate practical responses to the environmental changes which will be brought about by global warming.

The link between genetic conservation and global warming

One last point I should like to raise concerns the importance of germplasm evaluation per se. I believe that in due course, say in the next five years, we may have to justify why large sums of money are being spent on germplasm conservation. Since we are not concerned with establishing museum collections of germplasm, we shall have to demonstrate the importance of plant genetic resources for plant breeding. This may be difficult, since the actual utilization of germplasm collections is perhaps not as high as we might expect.

Climatic change is an environmental issue that is now clearly on the political agenda in many countries in Europe. Since the use of germplasm can be considered as one strategic response to global warming, it is important to stress the link between genetic resources conservation and this issue, in order to ensure continued support for genetic resources activities.

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