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Climate Change Research at SCRI

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Executive Summary

- *Projected climate change in northern Britain is for warmer and drier summers, warmer and wetter winters with less snow, and more extreme temperature and rainfall events. These changes will affect crop production and quality, disease susceptibility and resource (water, nutrients and radiation) acquisition and utilisation by plants.*

- *SCRI has a strong track record in responding to climate and environmental change, particularly in the development of appropriate management practices and the deployment of genetic resources to combat current and emerging pest and pathogen problems and abiotic stresses.*

- *Current research on the impacts of climate change includes the effects of climate on pests and diseases and on abiotic stresses such as drought and frost tolerance. Maintenance of biodiversity and the on- and off-site effects of carbon and nitrogen are part of the wider research agenda on environmental change.*

- *SCRI's future research programmes will include a greater focus for opportunities to mitigate and adapt to climate change. Mitigation research includes means of using plants to transfer carbon to soils, modifying carbon and nitrogen distribution and cycling, and improving nutrient use efficiency to reduce gaseous and leaching losses. Adaptation research includes identifying mechanisms and sources of durable resistance/resilience to diseases and abiotic stresses, genetic enhancement to cope with variable growing conditions, and the development of new food and non-food crops.*

- *This programme of research will address several of the policy issues raised in "Changing Our Ways – Scotland's Climate Change Programme", "Climate Change and Scottish Agriculture", and also contribute to the emerging Scottish Soil Strategy.*

Policy Context

The recently published “A Forward Strategy for Scottish Agriculture” (2006) recognises the need for Scottish agriculture to adapt and manage the risks associated with climate change, and to make its contribution to mitigation in a range of ways. This policy imperative needs to be placed in the wider context of environmental change which takes account of climate, biogeochemical (including plant nutrients and wastes), water, soils, and biodiversity changes induced by human activities and which are the subject of multiple policy directives and objectives.

“Climate Change and Scottish Agriculture” (2006) acknowledges the contribution that Scottish agriculture makes to changing the world’s climate and identifies the main challenges facing Scottish Agriculture as flooding and drought, pests and diseases, and changes in natural habitats and wildlife. SCRI’s expertise in arable soils will contribute to the development of a Scottish Soil Strategy that will provide a framework for soil and wider environmental protection.

The opportunities to reduce gaseous emissions through better fertiliser management, conserve organic matter in soils, and enhance the soil as a sink for carbon are outlined in “Changing Our Ways – Scotland’s Climate Change Programme” (2006) with the need for ongoing research acknowledged. Substantial elements of SCRI’s current research activity are directed towards these multiple policy objectives, recognising that trade-offs are necessary to achieve the range of goods and services demanded of Scotland’s rural landscape.

SCRI is an active participant in the Stakeholder Group established by the Scottish Government to develop an action plan for land managers to mitigate and adapt to climate change.

Figure 1 Measuring climate change at SCRI’s on-site weather station.

Climate Trends in Scotland

Over the next 75 years, if gaseous emissions continue unabated, the climate of northern Britain is likely to become up to:

- 3.5°C warmer in summer
- 50% drier in summer
- 40% wetter in winter
- 90% less snow
- 4 weeks earlier spring
- more extreme temperature and rainfall events
- 90% higher CO_2 levels
- higher UV-B and reduced ozone

Pragmatically, more extreme and variable weather, and changes in winter precipitation, will mean agronomic and cropping pattern changes too. The requirement for more resilient/adaptable crop genotypes with durable resistance coupled with functionally resilient soil and crop environments is, therefore, paramount.

Regional variations in the direction and magnitude of climate change will drive changes in cropping patterns with resultant socio-economic impacts on rural communities in particular. Developing crops able to not just tolerate but to advantageously exploit these changes, requires a comprehensive understanding of the crop genotype-environment interaction, where the environment includes the agronomy, ecology, abiotic and biotic stresses and end-user requirements.

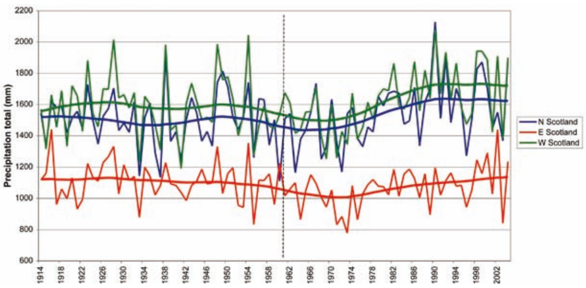

Figure 2 Precipitation total (in millimetres) each year for Scottish regions (green = west, red = east, blue = north), from 1914 to 2004, with smoothed curves to show a running average.

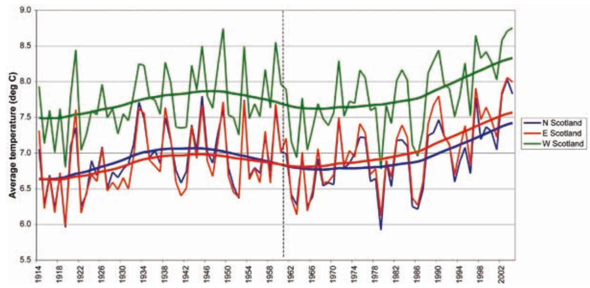

Figure 3 The average temperature (in ºC) each year for Scottish regions, from 1914 to 2004, with smoothed curves to show a running average. The vertical dashed line marks 1961.

Impact of Climate Change on Scottish Cropping Patterns

With our present knowledge, the scenario outlined above may result in less predictable crop protection requirements, more drought-stressed crops, and greater unpredictability of yield. In particular, changes to harvest, sowing and spraying conditions may lead to greater uncertainty for winter crops. Conversely, an earlier spring and higher CO_2 concentrations could benefit some crops if water is not subsequently limiting. The disease spectrum is likely to change, as existing pathogen populations shift and new pathogens appear, as will consequent epidemiological factors such as variability, over-wintering, and general aetiology.

Relatively little is known about the potential impact of climate change on crop quality although it is known that the protein content of grain is highly susceptible to current variations in climate, affecting the type of foods that can be produced by processors and food manufacturers. In order to develop appropriate adaptation strategies, predictions about changes in the quality, nutritional value and safety of food crops need to be considered in the context of the entire food chain from primary production to storage to distribution, processing and utilisation. SCRI is in a key position to contribute to this aspect of climate

Figure 4 The composition of aphid populations on potato crops may reflect changes in climate and in turn this will alter virus levels.

change impacts through its expertise in molecular physiology, biochemistry and analytical chemistry as complementary skills to genetics and breeding.

With climate change, though, will come other changes, and producers will try to alleviate the effects of the climate. Leaving aside changes driven from policy and economic considerations, such as increased planting of energy crops, which are not a direct consequence of environmental change, other changes are likely to be driven primarily by an assessment of risk factors affecting production into specific markets. Warmer mean temperature suggests that there is a potential for longer growing seasons for both winter- and spring-sown crops. Whether this potential is realised in practice will depend on whether more rainfall in winter prevents management operations in spring and whether drought prevents growth in the summer. Disease-susceptible cultivars will be even more disadvantaged than at present if there is greater difficulty in achieving optimum spray timings, so these will not continue to be grown unless customers pay more to reflect the risk. Current trends towards fewer pass operations (such as minimum tillage) and protected cropping for high value crops will continue and themselves influence disease, nutrient, water and biodiversity status.

Figure 5 Plants exhibiting climate change induced development problems now: blackcurrants with uneven budding.

Current Climate Change Research

SCRI has a strong track record in responding to climate and environmental change, particularly in the development of appropriate management practices and the deployment of genetic resources to combat new pest and pathogen problems, and abiotic stresses.

Specific areas of research include:

- Analysis of long-term climate records measured at Invergowrie to determine climate trends in the Dundee region. This analysis will be extended to examine crop yields and outbreaks of emerging diseases to quantify the existing impacts of climate change on current practices.

- The environment of soft fruit crops is an excellent example of where SCRI has developed solutions to cope with the new disease problems that arose first with machine harvesting and more recently with the change to growing in polytunnels. Moreover, long-term problems of root rots in soft fruit, late-blight on potato, and abiotic stresses such as frost tolerance have been tackled with genetic solutions involving considerable investment in germplasm resources and genetic and molecular mechanism research leading to durable resistance solutions.

- SCRI is developing an understanding of the resilience of cropping systems in response to environmental changes. A solid framework for understanding the functional interactions of crop ecology, essentially the biodiversity of the

Figure 6 Warmer wetter winters may increase the threat of raspberry root rot caused by *Phytophthora fragariae* var *rubi*

arable environment, has been developed. The key processes driving carbon and nitrogen cycling in these systems are being studied, and together these data have been used to refine research programmes that will better define sustainable arable systems.

- Roots are key to a plant's success, particularly to take up water and nutrients. Their interaction with the soil community and structure, and the genetic and environmental control of root growth and activity, has been the focus of much of our work. Variation in root architecture is a resource which has been developed as part of the barley TILLING population whereby useful genes (alleles) for adaptation to specific environments can be identified.

- Climate change and biodiversity interact in many important ways. The biodiversity of model crops (barley and potato) has been documented using molecular markers. This approach has become the keystone for collaboration in barley, allowing the demonstration of geneflow, the origins of important traits, and forming the basis of international resources to breed for response to climatic and other changes. Similarly in potato, the Commonwealth Potato Collection provides a diverse source of germplasm that can be utilised to incorporate traits giving tolerance to biotic and abiotic stresses. The bidiversity of pests and pathogens is also of major importance, with internationally recognised culture collections, e.g. *Phytophthora* and *Erwinia*, playing key roles in understanding population change, mechanisms of pathogenicity and the durability of resistance.

- Shifts in pest and pathogen populations and their geographic distribution occur as a result of climate changes. SCRI's development of diagnostics and markers has given us detailed knowledge of pest and pathogen epidemiology, geographic distribution and population structure which has, in turn, enabled us to develop informed strategies for crop protection and resistance breeding.

Planned Climate Change Research

In addition to on-going studies on the impacts of projected climate change on crops, SCRI research is evolving to include more activities on mitigation and adaptation.

Research on mitigation will include:

- The role of plants in effecting carbon transfer to soils. SCRI is a partner in the Scottish Alliance for Geosciences, Environment and Society consortium of Scottish Universities with significant environmental science research programmes in which it provides expertise in plant-mediated transfer of carbon to soils.

- Carbon and nitrogen cycling in ecosystems managed for crop production. Work as part of Scottish Government commissioned workpackages will examine how carbon losses to the atmosphere and nitrogen losses to water courses can be minimized.

- Improving nutrient use efficiency of crop plants to reduce gaseous and leaching losses. New research programmes will be instituted to achieve multiple policy objectives related to climate change, water, waste, soils and biodiversity.

Research on adaptation will include:

- Mechanisms and sources of durable disease resistance. SCRI's experience with long-standing problems such as root rots in soft fruit and late-blight on potato have been tackled with genetic techniques involving considerable investment in germplasm and genetic and molecular research resulting in durable resistance solutions. These resources will be deployed on the problems of new and emerging diseases.

- Identifying potential threats from new pests and pathogens of plants emerging in Scotland as a result of climate change, such as root-knot nematodes (*Meloidogyne* spp.), *Erwinia*

Figure 7 The climate change chambers at SCRI allow soil temperature profiles to be manipulated independently from the environment above ground, thereby creating conditions similar to those experienced by plants in the field. Environmental conditions are accurately controlled in the cabinets through a series of measurements and climatic adjustments at two minute intervals.

Figure 8 A new pathogen: disease symptoms on potato tubers caused by *Erwinia chysanthemi*

Figure 8 Photograph courtesy of L. Tsror, Gilat Research Centre, Israel

Figure 9 Lady Balfour, bred at SCRI for Greenvale AP, is the UK's best selling organic potato. It combines excellent cooking characteristics with disease resistance to late blight and Potato cyst nematode.

chrysanthemi and *Phytophthora ramorum.* Knowledge of pathogenicity mechanisms and how these organisms interact with their hosts and the wider environment will be used to deploy environmentally-benign and cost-effective control measures.

- Understanding of the role of climate change on the survival and movement of human and animal pathogens in the environment, and particularly their association with plants and soils.

- Mechanisms and sources of resistance/resilience to abiotic stresses including drought and cold. As above, germplasm resources will be directed to these ends.

- Genetic enhancement to cope with more variable growing conditions

- Development of new crops (including energy crops and those producing molecules of high value) to take advantage of more favorable growing conditions.

To undertake this research, SCRI will continue to invest in high quality research facilities including state-of-the-art analytical and profiling equipment, controlled environment chambers (including variable CO_2 atmospheres), field rain shelters, irrigation equipment, commercial-style polytunnels, disease nurseries, positive pressure, spoor-proof, air conditioned glasshouses, and humidity and chill controlled cabinets. SCRI is involved in many international projects such as the Generation Challenge Programme and EU projects on adaptation to droughted environments (e.g. MABDE) enabling us to identify and access germplasm that may have traits which enable crops to adapt to predicted climate change scenarios for Scotland.

In continuing to develop its research relevant to climate change, SCRI is developing partnerships with universities (e.g. the SAGES project) to enhance knowledge that can inform mitigation policies and practices, and with commercial bodies to ensure that knowledge and innovation that can benefit adaptation finds its way to market expeditiously.

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