Technical Note TN605

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ISSN 0142 7695 • ISBN 1 85482 871 1 • October 2007

Impact of Climate Change in Scotland on Crop Pests, Weeds and Disease

SUMMARY

- **The Scottish climate is going to get warmer with wetter winters and drier summers**
- **This is likely to increase many pest, weed and disease problems on crops over the next 50 years**
- **Some pests, weeds and diseases will become less of a problem**
- **New 'alien' pests, weeds and diseases from outside of the country, could arrive and establish themselves**
- **There will be a need to increase pest, weed and disease forecasting and monitoring to detect and eradicate any sporadic introductions of new problems and to manage problems already present in Scotland**
- **Changes in pest, weed and disease management will be required**

Introduction

Climate change is now an accepted phenomenon and its impact on Scottish agriculture will become more noticeable over the next 50 years. Over the last half century temperatures have increased in every season in all parts of Scotland, and in some areas in Scotland, particularly northern and western areas, winter rainfall has increased on average by 60%. Scotland will get warmer winters and summers, with an increase in winter rainfall but a decrease in summer rainfall, and with more extreme weather events. These changes in temperature and rainfall coupled with increases in carbon dioxide concentration will affect crops as well as the pests, weeds and diseases that live on or in them.

Much of the change that will happen to the Scottish climate over the next 50 years is already determined by past and present emissions of carbon dioxide and other so-called 'greenhouse gases', so any reduction of these emissions over the next decade or so will only slow down or alter the climate from 2050 onwards.

In this Technical Note we will summarise how climate change is likely to affect the pests, weeds and diseases we currently see on Scottish crops, and identify potential 'new' threats that can take advantage of the changed Scottish climate. We use predictions and forecasts for Scottish climate in 2050 as the basis for this Technical Note, which are derived from scenarios produced by the UK Climate Impacts Programme (UKCIP) and the Intergovernmental Panel on Climate Change (IPCC).

SAC receives financial support from the Rural and Environmental Research and Analysis Directorate of the Scottish Government

Table 1. The likely changes in Scottish climate by 2050

Climatic variable	Likely change
Temperature	Warming of between 1-2°C, with greatest warming during the autumn except for the extreme north of the country. There will be more extremes of temperature in the summer and autumn, with fewer very cold days, especially in the winter.
Rainfall	Winter rainfall will increase by 15-20%. Summer rainfall will decrease by 15-30%.
Humidity	Relative humidity will decrease slightly.
Soil moisture	There will be a reduction in soil moisture in the summer and autumn of between 10-30% except in the Highlands. Winter soil moisture will increase up to 10% from current levels.
Thermal growing season	This will increase in all areas allowing earlier sowing of crops to occur along with earlier harvests and potential for novel crops to be grown.

Impact of climate change on crops

The change in climate over the next 50 years will see improvements in yield for some crops, but losses in others.

Winter wheat will be sown later to prevent too much autumn growth, and spring growth will be earlier leading to earlier ripening with a subsequent reduction in grain weight and quality. The crop may require more nitrogen as the crop canopies will be larger, and soil moisture will be an issue during the drier summer months. Spring wheat may become more important in some areas.

Warmer springs will lead to earlier sowings and potentially higher yields of potatoes (up to 10%), and even the possibility of double cropping. However, crops will need more irrigation and potato blight could be a problem earlier in the season if crops are sown earlier. Maize and sunflowers could become alternative spring crops.

For horticultural crops accelerated plant growth may reduce yields and crop quality in some crops, although crop ranges will expand north and west, with new crops suitable in the south of the country. Perennial fruit and vegetable crops that require chilling could be adversely affected, and the advanced bud break in fruit crops such as raspberries will make them at risk from late frosts. There will be a higher risk of physical damage to crops from wind and intense summer rainfall events.

There is likely to be an increase in many pest and disease problems (including 'aliens') due to less 'winter kill', earlier appearance in the spring and summer, and more generations in a season. However, some pests and diseases will become less of a problem. Drought stressed crops will be more at risk from pests and diseases, and irrigation to thwart this will encourage some soil pests and diseases. Crop adaptation and plant breeding may circumvent problems to some extent, but pests and diseases have been adapting to climatic changes for the last century, so they have a head-start. There will be changes in use of pesticides on crops through earlier use, and the dry summer conditions will limit their efficacy to some extent.

Below we discuss several pest, weed and disease problems that will be affected by the change to Scotland climate over the next 50 years. Computer models allow us to predict how certain crop pests, weeds and diseases, not previously seen in the UK, may spread in the future as a result of climate change. This surveillance of threats from new problems provides an opportunity for SAC to take action before these problems arise - thereby minimising the threat to our food crops.

Diseases

Brown rust

Wheat brown rust (*Puccinia recondita*) is a major disease threat to crops in East Anglia, but until recently, has caused minimal economic damage in Scotland. When the susceptible wheat variety Riband was widely grown, brown rust epidemics in Scotland were rare. Cool summer temperatures are the key reason for keeping brown rust as a low priority disease. Today, the wheat variety Alchemy is a popular variety due to its good resistance against Septoria tritici. The variety is however very susceptible to brown rust. Growers should not ignore this disease weakness, since brown rust is likely to become an increasing threat in Scotland in the short term since the disease spreads rapidly in warm and humid weather conditions.

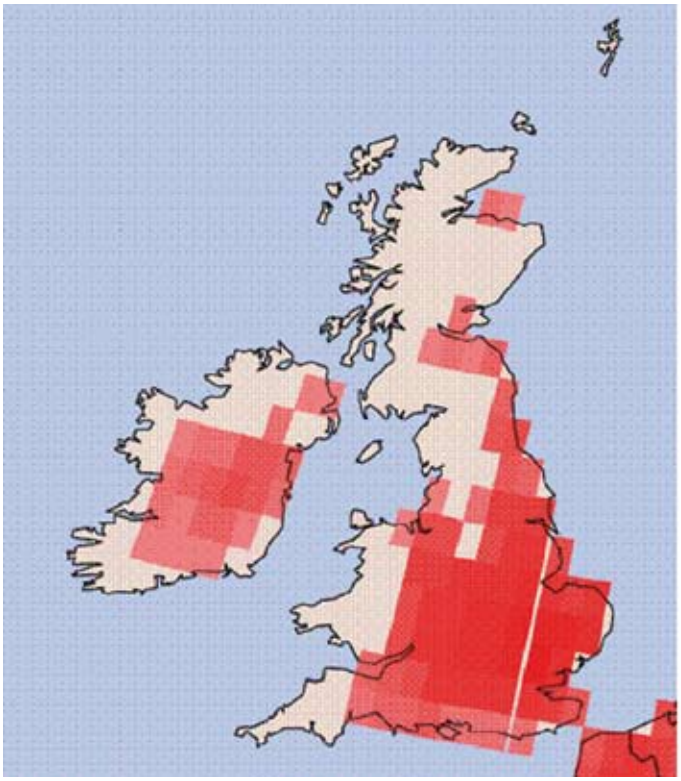
Brown rust levels are on the increase, especially following the 2007 season where a mild winter was followed by a warm spring. The risk from brown rust will be highest where wheat is sown early in August. A mild winter and a humid mild spring will also increase the risk and the disease is already established in crops throughout the UK. Early sowing means there was no gap between cropping seasons, providing the fungus with a green bridge to survive from one season to another. The mild winter also enables the disease to thrive with few frosts to kill out the fungus.

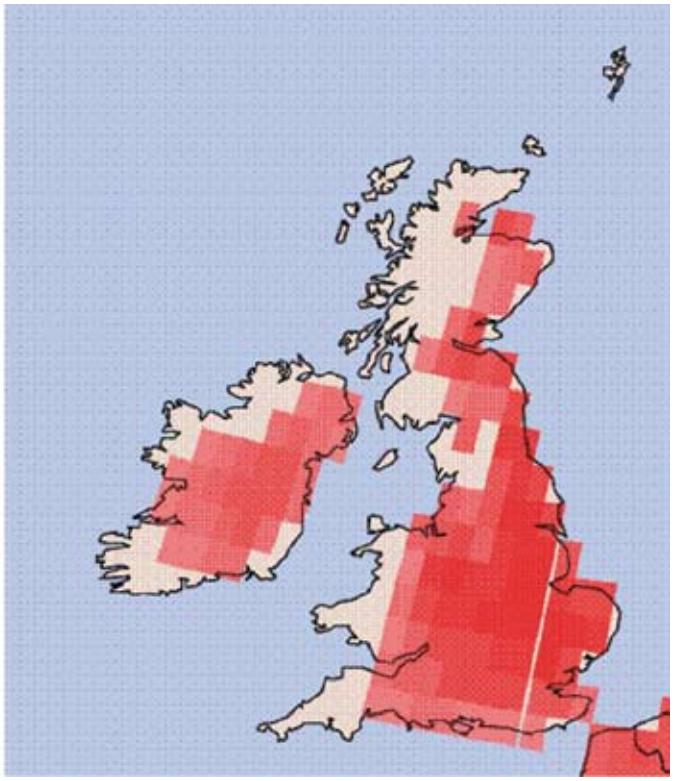
Brown rust epidemics are more likely to occur in Scotland in the next few years should spring and summer temperatures increase.

Figure 1 illustrates the areas currently at risk from brown rust and those areas at risk in the predicted climate for 2050.

Although we can reduce the impact of brown rust through the use of fungicides, these must be applied before the disease takes hold, since eradication is next to impossible. Fungicides should be seen as the last resort to managing disease. Market forces usually dictate variety choice based on the quality of the grain, but where possible, variety resistance alongside good agronomic practice should be used.
Regular crop monitoring funded by RERAD in Scotland, tracks the progress of this and other diseases, giving growers early warning to prepare for an outbreak.

Figure 1. Potential distribution of brown rust under average climate for the last 30 years (left) and predicted climate in 2050 (right). The darker the shade of red, the more suitable the climate will be for brown rust outbreaks.





Fusariums

Head blights including Fusarium species are not uncommon in Scotland today. Looking back over the last few seasons, information from the Official Seed Testing Station shows that in a normal year, between 70 and 95% of grain samples have some contamination with Fusarium species - but over 90% of these cases are at very low levels of less than 5%.

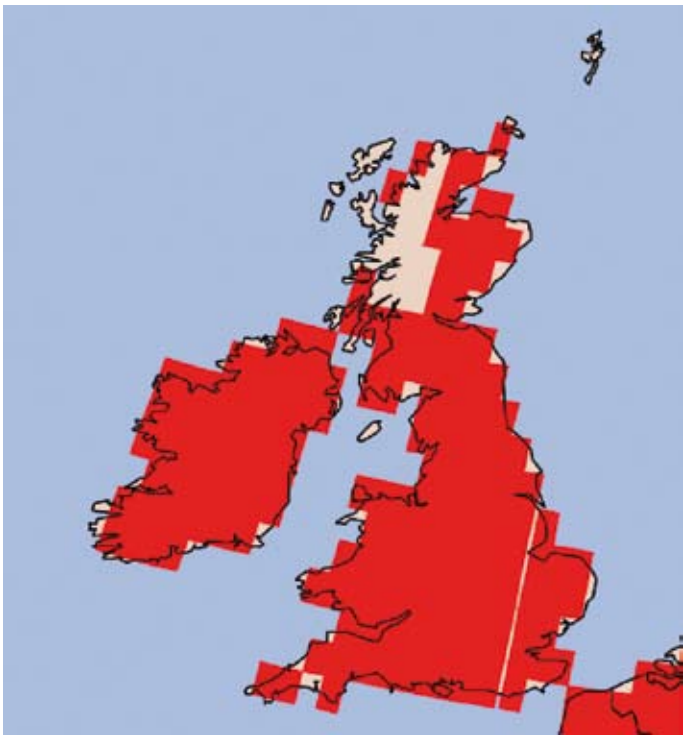
The fusariums are additionally problematic as some produce mycotoxins. These are highly toxic compounds, which remain present and stable through subsequent drying, milling and processing and which are subject to strict legislation as to maximum permitted levels. *Microdochium nivale* is the most common of the 'fusariums' isolated from grain and this fungus does not produce mycotoxins. Of the true fusariums found in Scotland we find *Fusarium culmorum* with relative frequency and *Fusarium graminearum* and *Fusarium avenaceum* occasionally. All of these Fusariums produce toxins.

Fusarium graminearum poses the greatest threat as a mycotoxin producer in mainland Europe, but is currently rare in Scotland. A future forecast of how climate change will impact on the severity of this pathogen is seen in the map on the right (Fig. 2). It shows a greater risk in the future throughout the east coast of Scotland up to Inverness.

A change in climate may also increase the probability of the sowing of more susceptible hosts. Growing maize in the rotation is a known risk factor for Fusarium production in cereals. A change to mild weather will increase the chances of more maize grown in Scotland, and hence increase the risk of Fusarium graminearum and the mycotoxins associated with it further.

The application of fungicides to the heads of cereals is known to reduce fusarium levels and hence mycotoxin production. Head fungicides are normal practice in Scotland and robust doses of triazoles form the backbone of the head spray. Strobilurins will reduce the sooty moulds but few will control the true fusariums.

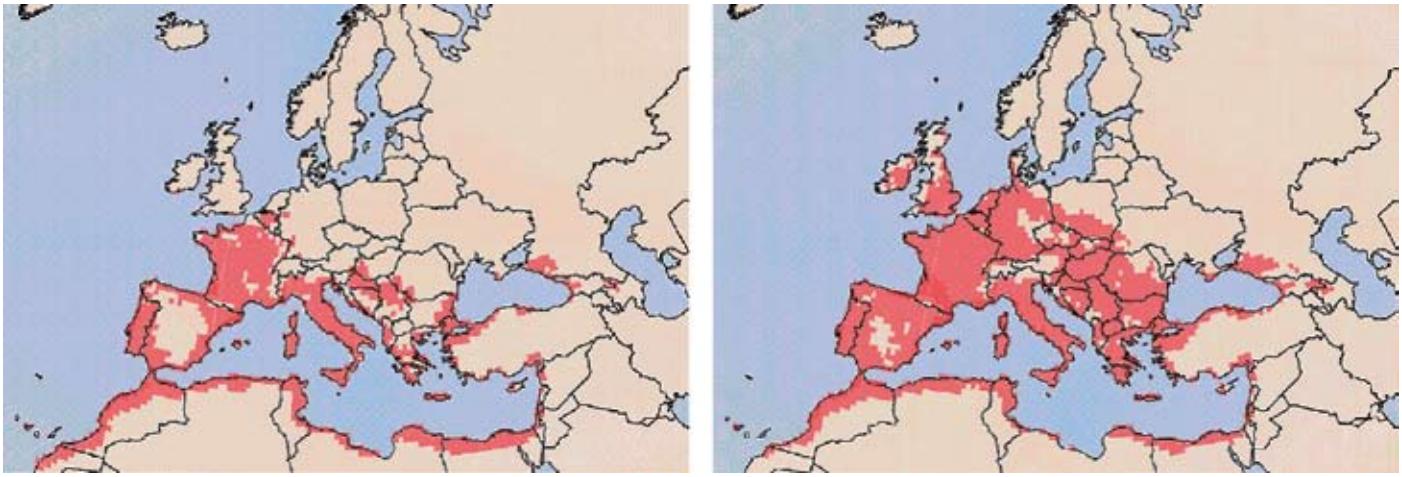
Figure 2. Areas (in red) at risk from Fusarium graminearum in climate predicted for 2050



Black stem rust

A new race of a disease called black stem rust, caused by the fungus *Puccinia graminis*, is on the move and posing a threat to many of the world's wheat growing regions. Although not a threat to UK wheat crops today, it is a potential new threat in 2050 (Fig. 3).

Figure 3. Potential distribution of black stem rust under average climate for the last 30 years (left) and predicted climate in 2050 (right).



The new fungal race of black stem rust was first found in Uganda in 1999 and has spread through wind and air currents to other regions in East Africa, including South Yemen.

Black stem rust is not unheard of in the UK today, and it has been known to attack wheat crops late in the season in the south and east of England. On the rare occasion it occurs, it is more a curiosity than an economic threat in the UK today. Should spores of this fungus reach Europe, the impact in the UK now will be minimal and nothing like as devastating as could occur in major wheat producing regions in Europe (Fig. 3).

The current climatic conditions in Uganda where the new race was found were incorporated into a climate matching model and the results confirmed the current thinking that there is no immediate risk to the UK (Fig. 3).

However, comparing the current Ugandan climate to that forecast for 2050 shows black stem rust risk will spread further north in Europe, covering the main wheat growing regions in the UK (Fig. 3).

In common with other related diseases, such as wheat yellow rust (*Puccinia striiformis*), black stem rust is best managed by breeding resistant varieties that are better able to fight the fungus,

Pests

The impact of climate change on pests of crops is driven by the response of insects to temperature and carbon dioxide. Some pests such as cereal aphids will reproduce more rapidly at the elevated carbon dioxide levels forecast for 2050, and temperature increases will accelerate the rate of multiplication even further, allowing more generations per season (up from 18 to 23 for some aphid species). This inevitably has consequences for the crops that aphids infest, particularly for crops such as seed potatoes where virus transmission by aphids is a potential threat.

Increases in the rate of reproduction and the number of generations a season will also increase the risk of certain pests becoming resistant to insecticides.

The milder winters will allow more pests to survive the winter and lead to earlier infestations of crops. The mild winter of 2006/2007 is indicative of the winters we are likely to experience in 50 years or so, and this year led to very early peach-potato aphid (*Myzus persicae*) and potato aphid (*Macrosiphum euphorbiae*) flights, with many crops of potatoes being infested with aphids as soon as they emerged, increasing the threat of virus transmission by aphids into seed potato crops, and consequently requiring aphicide treatments from crop emergence onwards.

We are already seeing 'new' pest problems arising in Scottish crops which are, in part, in response to climatic changes: cabbage stem flea beetle and rape winter stem weevil in winter oilseed rape and orange wheat blossom midge in cereals for example.

Pests already present in Scotland are also becoming more problematic: a 3rd generation of cabbage root fly in September used to be the exception but is now regularly occurring, wheat bulb fly and leatherjacket populations are steadily increasing, as is the threat from cereal leaf beetle grubs (Fig. 4).

As the Scottish climate changes over the next 50 years, many of these pests will become serious problems (see Table 2).

The threat from pests not yet in the UK is increased as the Scottish climate will become more suitable for these pests to survive and breed. For example, the climate in some areas of Scotland could be suitable for survival of Colorado potato beetles as early as 2020 should it be introduced into Scotland. By 2050, wide areas of Scotland will be suitable for Colorado beetle survival (Fig. 5).

Other pests have already been introduced into the UK and have established themselves. Turnip sawfly for example was eradicated from the UK but has re-established and caused serious damage to winter oilseed rape in the autumn of 2006. By 2050 it is likely to have spread from central, southern and eastern counties of England to the eastern and central areas of Scotland up as far as Inverness.

Some pests such as wheat bulb fly will decrease in severity, as the wetter winters will lead to a higher level of winter kill, making areas where the pest is currently endemic unsuitable for its survival. This increase in winter rainfall will make the north and west of Scotland most favourable for the survival of grey field slugs, as summer rainfall will not change much, however the reduction in summer rainfall in the east of Scotland will not favour slugs, so crops grown in the east will be able to breathe easier in terms of slug problems in 50 years time.

Fig. 4. Potential distribution of cereal leaf beetle under average climate for the last 30 years (left) and predicted climate in 2050 (right). The darker the shade of red, the more suitable the climate will be for cereal leaf beetle survival and reproduction.

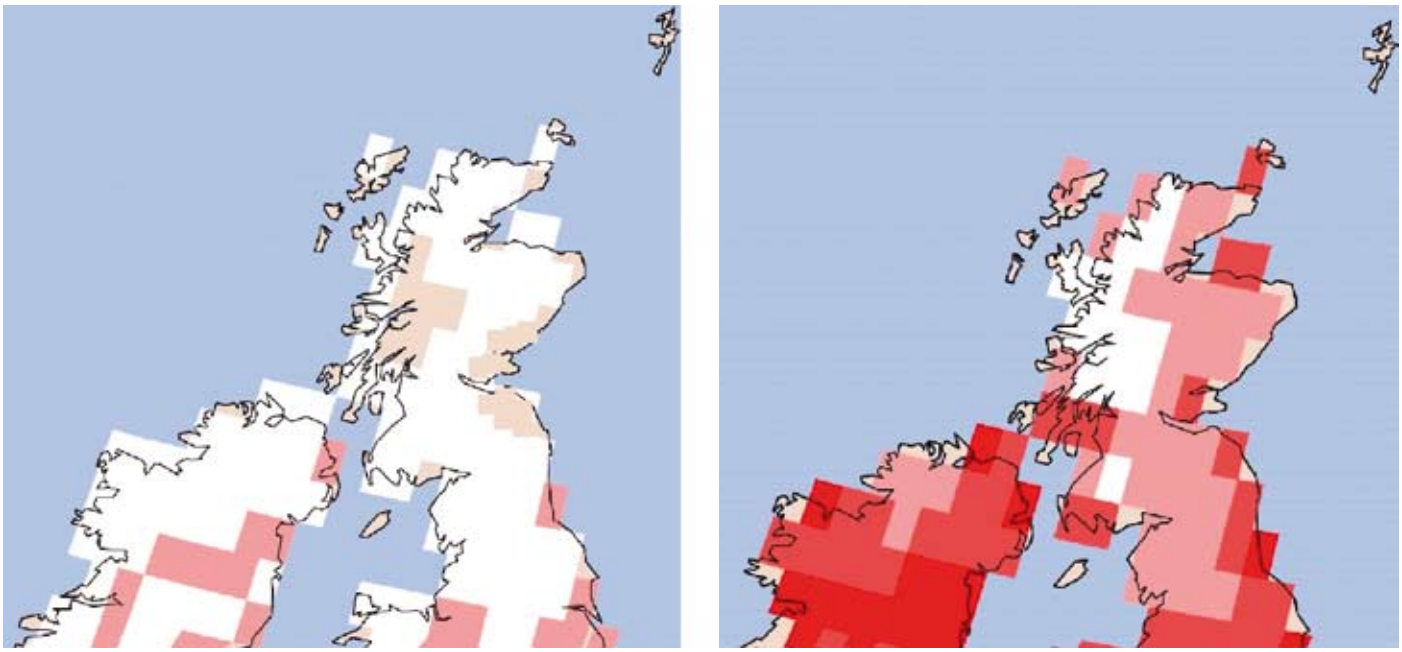
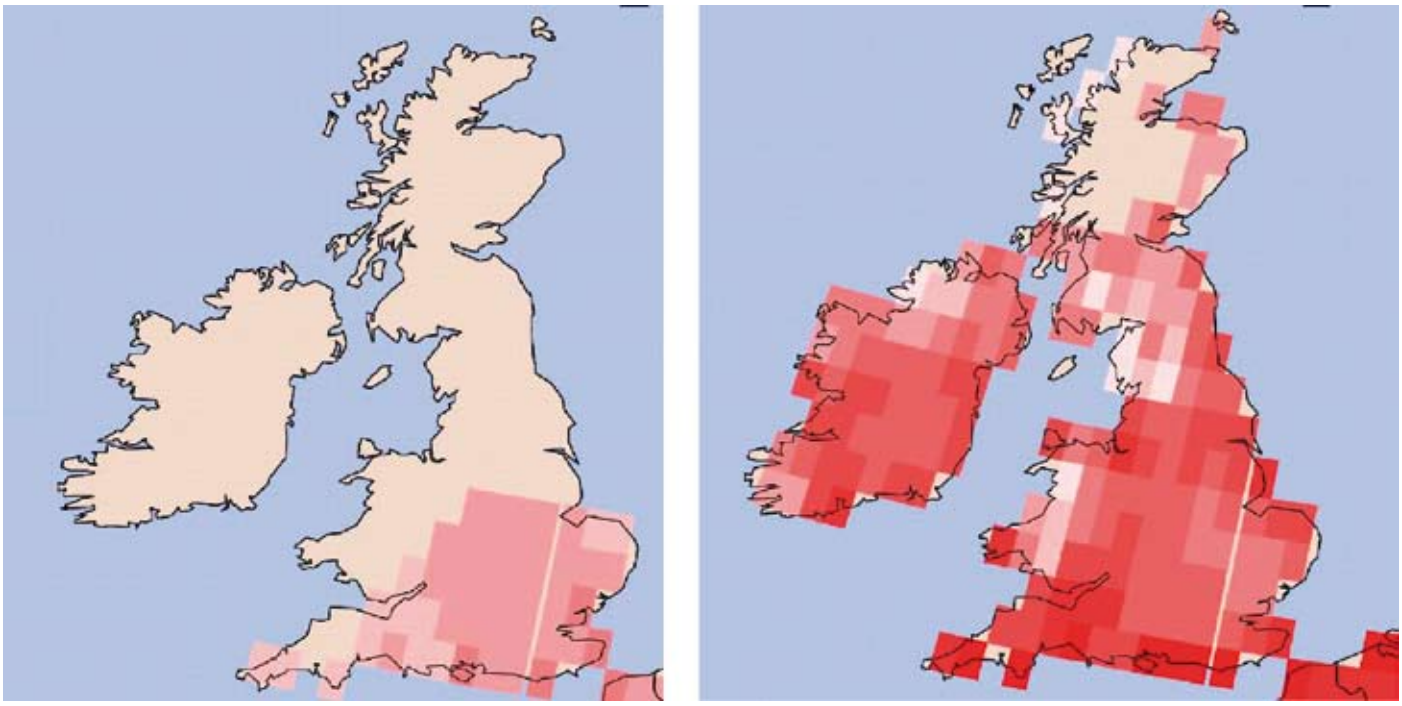


Figure 5. Potential distribution of Colorado beetle under average climate for the last 30 years (left) and predicted climate in 2050 (right). The darker the shade of red, the more suitable the climate will be for Colorado beetle survival and reproduction.



Weeds

In this section we examine the potential changes in weed populations related to predicted climatic changes up to 2050. This uses known differences in weed species and populations between south-east England and western European mainland and arable areas of Scotland, taking into account differences in soil types and characteristics, but not cropping differences. The current differences in weed species in part probably reflect current climatic dissimilarity – notably warmer, drier growing seasons in south-east England and wetter, cooler winters in Scotland.

Grass weeds

The climatic models suggest a future of warmer, drier summers and wetter, warmer winters in eastern Scotland. This appears to indicate a climate increasingly similar to that current in eastern England, although winter rainfall levels may be higher, and possibly more like that of western France. This would initially suggest an increasing trend in winter-based rotations towards grass weed problems such as sterile/barren brome (*Anisantha* or *Bromus sterilis*, and black-grass (*Alopecurus myosuroides*)), and meadow-brome (*Bromus hordaceous*)

currently rare or very rare in Scotland. This would be particularly evident on heavier soils. It is noted in SAC records that black-grass sightings have increased significantly in the last 5 seasons in heavier soils in southeast Scotland, whilst meadow-brome (4 recordings) has only appeared since 2002. These weeds would be expected to increase in the short to medium term.

Surprisingly, the climate model, however, suggests a reduction in black-grass in England and Scotland by 2050 (Fig. 6). It is unclear why this should happen, but may be related to the very dry summer predictions. Some of the brome species are warmer, drier climate species, and may be expected to increase: these include meadow brome, rye-brome (*Bromus secalinus*) and soft brome (*Bromus mollis*).

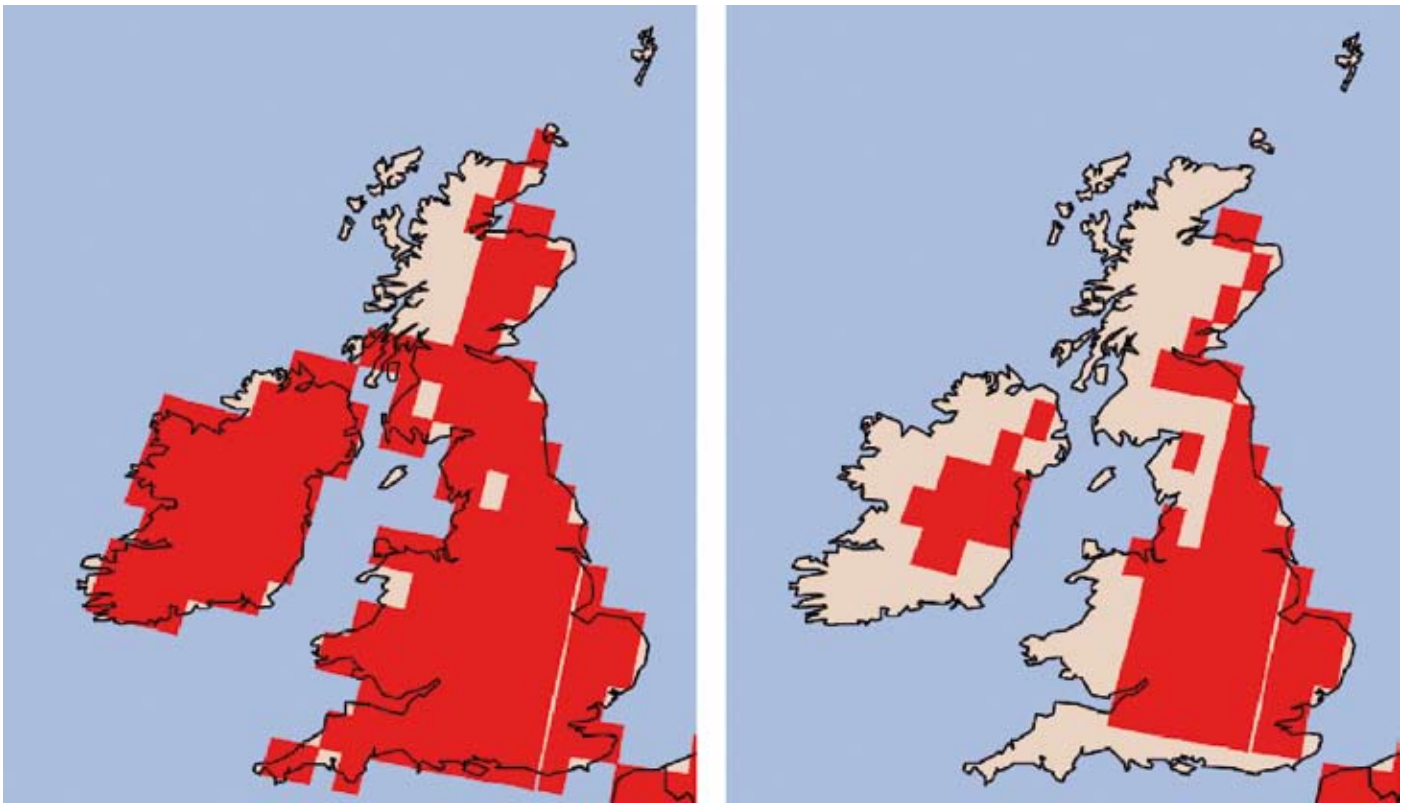
It has been suggested that loose silky-bent (*Apera spica - venti*) a major weed in central Europe, but rarely seen in UK, would increase, especially on lighter soils. However, Although summers are warm in central Europe, winters are very cold and dry.

Table 2. Likely increase or decrease in severity of specific crop pests by 2050

Common name	Crops affected	Increase/decrease in severity
Turnip sawfly	Oilseed rape, brassica vegetables	Increase
Gout fly	Cereals	Increase
Wheat stem sawfly	Wheat	Increase
Wheat bulb fly	Wheat and spring barley	Decrease
Aphids	All crops	Increase
Cereal leaf beetle	Cereals	Increase
BYDV	Cereals	Decrease but threat of new strains
Wireworm	Cereals, potatoes	Increase
Colorado beetle*	Potatoes	Increase
Root knot nematodes*	Potatoes, field vegetables	Increase
Pea moth	Peas	Decrease
Potato cyst nematode	Potatoes, tomatoes	Increase
Diamondback moth	Brassica vegetables	Increase
Carrot fly	Carrots, parsnips	Decrease
Cutworm	Field vegetables, potatoes	Increase
Slugs	All crops	Decrease, except in the north
Japanese beetle*	All crops	Increase

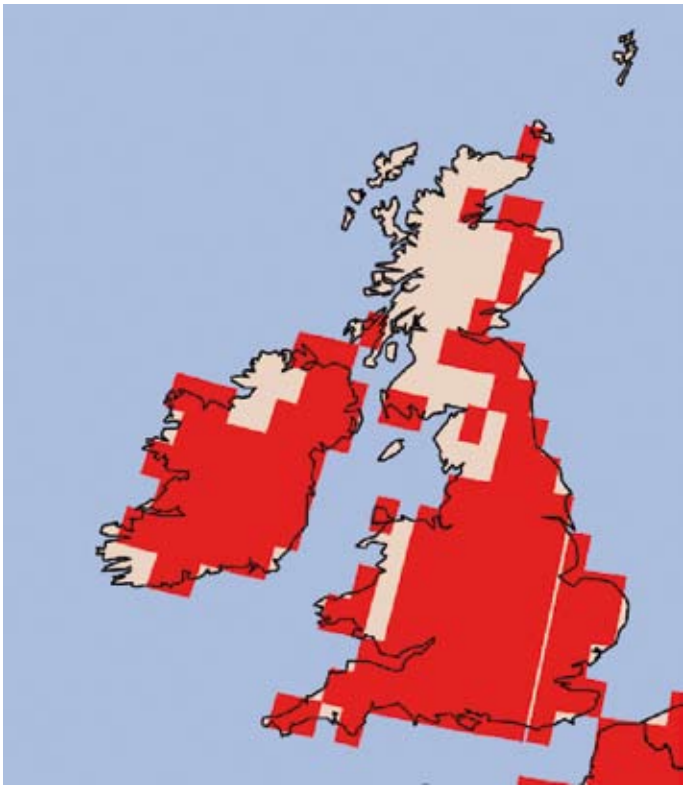
** Pests not yet established in the UK*

Figure 6. Potential distribution of black-grass under average climate for the last 30 years (left) and predicted climate in 2050 (right).



Examining grass weeds from warmer zones of Europe there are suggestions that barnyard grass (*Echinochloa crus-galli*) and crab-grass (*Digitaria sanguinalis*) could become important in the UK as well as annual rye-grass (*Lolium annua*) in the longer term. The climate model does suggest that the climate in parts of Scotland in 2050 will have a match with that of areas of France where barnyard-grass is a significant problem now (Fig. 7). These weeds are more likely to cause problems in spring-sown crops such as maize, and certainly more extensive maize growing could be possible in Scotland by 2050. Other grass weeds that are problems in southwestern France, which currently has a warm, moist climate, could also become problems.

Fig. 7. Potential distribution of barnyard grass in 2050 based on current climate of Bordeaux, France where the weed is endemic.



Broad-leaved weeds and meadow-grasses

We should also look at warm, moist winter climate and dry/warm summer climate for broad-leaved weeds in the future. Some weeds currently major problems in Scottish winter crops, such as annual meadow-grass (*Poa annua*), common chickweed (*Stellaria media*) and ivy-leaved speedwell (*Veronica hederifolia*), may not survive long into warm dry springs. On the other hand, cleavers (*Galium aparine*) would still be a problem and poppies (*Papaver species*) and various umbellifers and weedy crucifers may become more serious, even in the medium term.

In spring crops, more field bind-weed (*Convulvulus arvensis*), scarlet pimpernel (*Anagallis arvensis*) and various composite species (*Compositae*) would be expected to increase. Some species such as pigweeds (*Amaranthus species*), already seen in southeastern England as new species, may become important. Other species, common in parts of continental Europe, such as thornapple (*Datura stramomium*) and black nightshade (*Solanum nigrum*), are serious and poisonous weeds in grain, vegetable and salad crops, and may become important. They are seen now as temporary 'visitors' in Scotland.

Grassland weeds

Warm, dry summers may reduce grassland in eastern Scotland, but, along with mild, wet winters, prolong the western Scotland growing season. This may mean a longer growing season for currently common perennial weeds such as broad-leaved dock (*Rumex obtusifolius*) and creeping and spear-thistles (*Cirsium arvense* and *C. vulgare*). More curled dock (*Rumex crispus*) may be found in drier summers in freer draining soils, whereas new thistle species may add to problems (e.g. musk thistle (*Cirsium nutans*).

New vetches (e.g. *Vicia* and *Lathyrus* species), clovers (*Trifolium* species) and more composite species (*Compositae*) similar to dandelions and cat's-ears are expected, again particular in dry, warm summers, but chickweed growth may be restricted to autumn/winter in the longer term.

Table. 3 Important weeds that may appear (A) or increase (I) in Scottish autumn-sown arable crops by 2050

A or I	Latin name	Common name	Favoured sites
I	*Alopecurus myosuroides*	Black-grass	Fertile soils, reduced tillage
I	*Anisantha sterilis*	Sterile/barren brome	Fertile soils, reduced tillage
I	*Anisantha commutatus*	Meadow brome	Fertile soils, reduced tillage
A/I	*Bromus secalinus*	Rye-brome	Fertile soils, reduced tillage
I	*Bromus gigantea*	Giant brome	Fertile soils, reduced tillage
I	*Buglossoides species*	Bugloss, field gromwell Greater Venus's looking-glass etc	Light soils, lower pH
I	*Fumaria species*	Fumitory species	Loams
A	*Papaver rhoeas*	Common poppy	Nutrient rich soils
A	*Papaver argemone*	Prickly poppy	Drier soils
A	*Papaver dubium*	Long-headed poppy	Loose, loams
I	*Sonchus species*	Sow-thistles	Fertile soils, not too dry
A	*Vicia* and *Lathyrus species*	Various tares and vetches	Loams

How successful rushes would remain is less certain. Their winter growing season would increase, but dry summers may reduce their spread. Soft rush (*Juncus effusus*) is by far the most common weedy form in Scotland, but hard rush (*Juncus inflexus*), much more common in parts of England and Wales, may become more evident in warmer conditions on more neutral/basic soils and jointed rush (*Juncus reticulatus*) in wetter, acid soils.

Bracken (*Pteridium aquilinum*) is very tolerant of warm conditions but may be less vigorous in drier summer areas in the east, but even more vigorous in the wetter west and north of Scotland.

Potential changes in the appearance and prevalence of weeds in autumn-sown crops, spring-sown crops and grassland are summarised in Tables 3, 4 and 5 respectively.

New crops may appear as weed species, such as hemp, sunflowers, various oil crops, attracted by more suitable weather conditions.

Table 4. Important weeds that may appear (A) or increase (I) in Scottish spring-sown crops by 2050

A or I	Latin name	Common name	Favoured sites
A	*Amaranthus species*	Pigweed species	Warm, lighter soils, fertile
I	*Avena fatua*	Spring wild-oat	Fertile soils
I	*Buglossoides* species	Alkanets, field gromwell, barage, Bugloss, hound's tongue, Viper's bugloss	Lighter, drier soils
I	*Bromus mollis*	Soft brome	Early sown, light land
I	*Carderia draba*	Hoary cress	Free drainage
I	*Chenopodium* species	Various goose-foots, fat hen	Fertile soils
I	*Convulvulus arvensis*	Field bindweed	Dry, fertile soils
A/I	*Datura stromomium*	Thorn-apple	In maize, fertile
I	*Descurainia sophia*	Flixweed	Sandy soils
A	*Digitaria* species	Crab-grasses	Warm, moist soils
A	*Echinochloa crus-galli*	Barnyard-grass	Warm, moist soils
I	*Erodium cicutarrum*	Common stork's -bill	Light, draining soils
I	*Euphorbia* species	Spurge species	Drainage, damp soils
A	*Galinsoga parviflora*	Gallant-soldier	Rich, sandy soils
I	*Geranium* species	Crane's-bills	Fertile loams
I	*Solanum nigrum*	Black-nightshade	Nutrient-rich loams
I	*Sonchus* species	Sow-thistles	Fertile soils
I	*Cirsium* species	Various thistles	Loams

Table 5. Important weeds that may appear (A) or increase (I) in Scottish grassland crops by 2050

A or I	Weed group	Common name	Favoured sites
A	*Digitaria* species	Crab-grasses	Moist, fertile soils
A	*Echinochloa crus-galli*	Barnyard-grass	Moist, fertile soils
I	Various composite weeds	Hawkbits, cat's-ears, hawk's beards, ox-tongues and related species	Drier, free-draining soils
I	Various vetches and clovers	Red, crimson, subterranean clovers	
I	*Carduus nutans*	Musk-thistle	
I	*Onopordum acanthium*	Cotton-thistle	
I	*Rumex* species	Docks	Fertile soils
I	*Pteridium aquilinum*	Bracken	Moister, fertile soils
I	*Juncus effusus*	Soft rush	Warmer, damper places
I	*Juncus reticulatus*	Jointed rush	Warmer, damper places

Summary

Many familiar pests, weeds and diseases will become more problematic over the next 50 years due to localised climate change. However, some will become less of a problem, as the wetter winters and drier summers, especially in the eastern side of the country will be less suitable for their survival. Of course if crops are irrigated to alleviate drought stress then these problems could still be with us. The drier summers will affect the efficacy of pesticides, and timings of pesticide use will change as pest and disease patterns on crops will alter.

The Scottish climate in 2050 will be suitable for a range of pests, weeds and diseases that don't occur in the country at the moment. They could arrive from England or from outside of the UK and create new problems for Scottish growers to contend with.

There will be changes in the crops that are grown, with the introduction of new varieties that can cope with potential drought stress, earlier sowing and harvest, as well as 'new' crops such as maize, durum wheat and vegetable crops such as onions becoming more suitable for the Scottish climate.

To cope with the changes in pest, weed and disease profiles affecting Scottish crops, forecasting and monitoring needs to be prioritised so that pest, weed and disease management programmes can be integrated with the changes required for successfully crop production under a changing climate.

Authors:

Ken Davies
Weed and Vegetation Specialist
SAC
Bush Estate
Penicuik
EH26 0PH
ken.davies@sac.co.uk

Andy Evans
Researcher (Entomology/Nematology)
SAC
West Mains Road
Edinburgh
EH9 3JG
Phone 0131 535 4093
andy.evans@sac.ac.uk

Simon Oxley
Senior Researcher (Plant Pathology)
SAC
West Mains Road
Edinburgh
EH9 3JG
Phone 0131 535 4094
simon.oxley@sac.ac.uk

This note was written and funded as part of the Crop Health Advisory Activity funded by the Scottish Government RERAD