FUNGAL ECOLOGY 5 (2012) 53–61

available at www.sciencedirect.com

ScienceDirect

journal homepage: www.elsevier.com/locate/funeco

Impacts of changing climate and agronomic factors on fusarium ear blight of wheat in the UK

Jonathan S. WEST[a,*], *Sarah HOLDGATE*[a,1], *James A. TOWNSEND*[a], *Simon G. EDWARDS*[b], *Philip JENNINGS*[c], *Bruce D.L. FITT*[a,2]

[a]*Rothamsted Research, Harpenden AL5 2JQ, UK*
[b]*Harper Adams University College, Newport TF10 8NB, UK*
[c]*The Food and Environment Research Agency, Sand Hutton, York YO41 1LZ, UK*

ARTICLE INFO

Article history:
Received 18 January 2011
Revision received 28 February 2011
Accepted 1 March 2011
Available online 12 May 2011
Corresponding editor: Lynne Boddy

Keywords:
Deoxynivalenol (DON)
Food security
Fusarium head blight
Mycotoxins
Risk prediction
Wheat scab

ABSTRACT

Climate change will have direct impacts on fusarium ear blight (FEB) in wheat crops, since weather factors greatly affect epidemics, the relative proportions of species of ear blight pathogens responsible and the production of deoxynivalenol (DON) toxin by two *Fusarium* species, *F. graminearum* and *F. culmorum*. Many established weather-based prediction models do not accurately predict FEB severity in the UK. One weather-based model developed with UK data suggests a slight increase in FEB severity as a direct effect of climate change. However, severity of the disease is likely to increase further due to indirect effects of climate change, such as increased cropping of grain maize, since maize debris is a potent source of inoculum of *F. graminearum*. To guide strategies for adaptation to climate change, further research on forecasting, management options to reduce mycotoxin production, and breeding for resistant varieties is a high priority for the UK. Adaptation strategies must also consider factors such as tillage regime, wheat cultivar (flowering time and disease resistance) and fungicide use, which also influence the severity of FEB and related toxin production.

Introduction

Climate change can increase the range and severity of plant disease epidemics (Garrett *et al.* 2006). Such increases can threaten global food security if they affect staple food crops in agricultural ecosystems especially in the developing world (Chakraborty *et al.* 2000; Anderson *et al.* 2004; Garrett *et al.* 2006; Schmidhuber & Tubiello 2007). Crop disease epidemics cause instability in food supply, which can lead to famine, conflicts and mass-movement of people to more favoured areas (Stern 2007). Climate change can directly affect plant pathogens by providing a climate that is more or less favourable to the pathogen (for infection, colonisation, reproduction or dispersal). Several successive years of favourable climate can potentially cause a build-up of inoculum, leading to epidemics that are much more severe than when a single favourable year occurs. Furthermore, climate change can indirectly affect crop diseases, for example by provoking adaptation strategies that involve changes to crop rotations to include new crops that are additional hosts to particular pathogens.

The weather in the UK is relatively variable compared to that of continental Europe, with large differences in monthly rainfall typically occurring during a year despite the long-term

* *Corresponding author*.
E-mail address: jon.west@bbsrc.ac.uk (J.S. West).
1 Current address: RAGT Seeds Ltd., Grange Road, Ickleton, Saffron Walden CB10 1TA, UK
2 Current addresss: University of Hertfordshire, Hatfield, Herts AL10 9AB, UK
1754-5048/$ – see front matter
doi:10.1016/j.funeco.2011.03.003

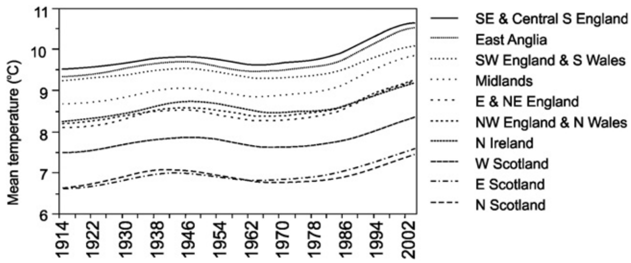

Fig 1 – Annual mean temperature from 1914 to 2004 for different regions of the UK, smoothed with a triangular kernel filter with 14 terms on either side of each target point. © Crown copyright 2006, the Met Office, used with permission.

average monthly rainfall at any given location being almost the same each month. Fig 1 shows a smoothed line of best fit to the annual mean temperature in different regions of the UK, which varied more with location than the variation at a single region over the period 1914–2004. UK Climate Impacts Programme (UKCIP; www.ukcip.org.uk, accessed 01.03.11) projections of future weather vary depending on which of many climate change scenarios are used but the general consensus is that the UK is predicted to have a warmer climate (e.g. +2 °C in winter to +4 °C in summer), with slightly wetter winters and drier summers (Semenov 2009; Fig 2). The UK is also predicted to experience much more intense weather events. These are the best estimates of future climate change available, although some alternative scenarios have been suggested.

The UKCIP projected weather would advance the date of onset of wheat anthesis (by approximately 2 weeks by 2050) and maturity for harvest (by 3 weeks) (Semenov 2009; Madgwick et al. 2011). 'Mediterranean-type' wheat cultivars, which respond to different environmental cues determining the time of flowering, typically flower 2 weeks earlier than current UK cultivars. Adoption of this kind of cultivar in the

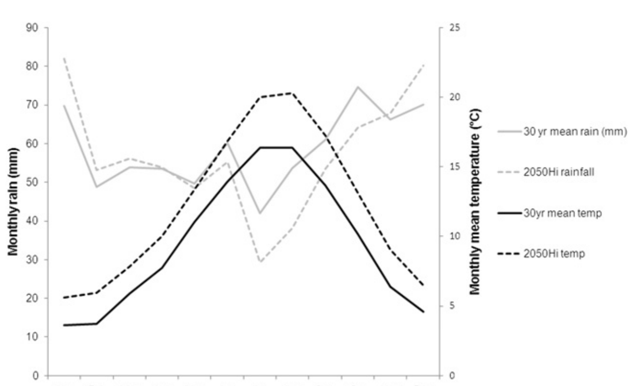

Fig 2 – Baseline 30-yr (1971–2000) monthly mean rainfall and temperature at Rothamsted, UK (51° 48′ 0″ N, 0° 21′ 0″ W) and projected monthly means for 2050 according to the high emission (2050HI) climate scenario HadRM3 model (see - http://ukclimateprojections.defra.gov.uk/content/view/561/690/, accessed 01.03.11.)

UK, proposed as an adaptation strategy to avoid heat stress at flowering, could advance the time of flowering by at least another week to mid-May in southern England. Such adaptation strategies may have unexpected consequences in terms of their effects on diseases to which the crop is susceptible during flowering, such as fusarium ear blight (FEB).

FEB, also known as fusarium head blight or scab, is a serious disease of small grain cereals, caused by a complex of many different species in the genera *Fusarium* and *Microdochium*, and now under the influence of climate change (Xu & Nicholson 2009). Of these, two species, *Fusarium graminearum* (teleomorph, *Gibberella zeae*) and *Fusarium culmorum* (no known teleomorph) are of concern in the UK because they produce a range of toxins that can contaminate grain, particularly deoxynivalenol (DON) (Parry et al. 1995; Fernandez & Chen 2005). Due to health concerns, EU legislation limits DON levels at 1250 $\mu g\,kg^{-1}$ in unprocessed wheat, with lower limits for various processed foods. DON concentrations of up to 600 $mg\,kg^{-1}$ in naturally infected grain have been reported (Sinha & Savard 1997); hence two or three severely-infected grains per 1,000 grains can put a batch close to the rejection limit. In the UK, in most years, few grain samples exceed DON thresholds [e.g. 0–5 % of loads have exceeded thresholds since 2001, except in 2008 (10.2 %) (http://www.hgca.com, accessed 01.03.11)] but it is not clear how the risk of mycotoxins will change with changes to climate and agronomic factors. Furthermore, the toxin zearalenone is also produced by *F. graminearum* and *F. culmorum*, while toxins such as HT2 and T2 are produced by other species of *Fusarium*, including *F. poae* and *F. langsethiae*, which are common in Scandinavia. There are indications that strains or species that are favoured by warmer climates can produce these and many other toxins (Jestoi et al. 2009). In commercial practice, the lightest grains, which can be heavily infected, are usually removed at combine harvesting. However, FEB and contamination by mycotoxins remain major concerns.

In addition to mycotoxin risk, it is not clear whether climate change will affect other aspects of FEB such as diseased ears to senesce prematurely (Fig 3A), leading to shrivelling of infected grain (Fig 3D) and substantial yield losses, ranging from 5–75 % (Parry et al. 1995; Lin et al. 2004). There is also often an associated stem base infection, fusarium foot rot, caused by the same pathogens (Bateman et al. 2007; Fig 3C), that can contribute to these yield losses and act as a source of inoculum for ear infection. Furthermore, the bread-making quality of infected wheat grains is also reduced due to their decreased protein and starch content (Parry et al. 1995). There is a concern that with changes in climate, more severely infected batches of grain may be rejected by millers on grounds of poor quality.

DON is produced primarily during infection of the ear by *F. culmorum* and *F. graminearum* when water availability is high, which in the UK is usually before harvest, rather than in storage as farmers store grain at <15 % (Gilbert & Tekauz 2000; Jennings et al. 2004a, b; Hope et al. 2005; Chakraborty & Newton 2011). A delay to harvest, caused by wet weather, can substantially increase DON production (Anonymous 2009b). DON is thought to play a role in virulence (Proctor et al. 1995; Jansen et al. 2005; Maier et al. 2006) and possibly (along with other trichothecenes) in competition against other fungi.