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Review

Challenges for crop production and management from pathogen biodiversity and diseases under current and future climate scenarios – Case study with oilseed Brassicas

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ABSTRACT

Climate change not only influences agricultural and horticultural crops but also the diseases that affect them. The different parameters associated with climate change, such as warmer temperatures, increased levels of CO_2, decreased rainfall and increased rainfall variability, have been widely studied in terms of their influence on different aspects of pathogens and diseases across various crops. This includes pathogen life cycle, expression of host resistance, disease epidemiology and severity of disease epidemics, as well as pathogen inoculum production. Less well studied are the potential changes in pathogen biodiversity, such as development of races or pathotypes, in response to climate change. Future changes in both pathogen diversity and pathogen threats are built on the complex changes in crops and agricultural practices that can occur with or without climate change. Pathogens are successful opportunists that occupy any niche that is not adequately protected by crop protection strategies, including host resistance. Climate change will influence future changes in the distribution and the challenge of future pathogen threats and corresponding changes in pathogen diversity. Fungal and oomycete pathogens occurring on oilseed Brassicas provide strong indications of the abilities of pathogens to readily adapt to changes in climate, including changes in crops or cropping systems in response to future climate scenarios. Some existing climates, such as Mediterranean climates and regions, are historically highly variable in terms of environmental parameters, including the amount, timing and variability of temperature and rainfall. These environments offer significant prospects for gaining a better insight and understanding of the processes involved with pathogen adaptation to future climate scenarios. While there have been attempts to date to define future expansion or contractions of some particular diseases in relation to future climate scenarios, including some diseases occurring on oilseed Brassicas, defining future distribution ranges of the most important pathogens, their races, and consequent disease challenges in relation to future climate changes remains an area of high priority. This information is critical for monitoring such changes over time and also for designing pre-emptive management strategies against pathogen threats for crops under future climate scenarios. Surprisingly, relatively little has been defined in terms of traits such as increased frequency of drought, higher temperatures, unpredictable and erratic wetting and drying cycles, salinity and inundation events in terms of the genes that determine differences in tolerance to such traits. Oilseed Brassicas include a range of different species making them an ideal prospect for use as a 'model' plant grouping for investigating and modelling impacts of biotic and abiotic stresses and their interactions under future climate scenarios. As a first step, the anticipated shifts in biotic and abiotic stress thresholds that occur across current environments for established and new *Brassica* crop species as a result of climate change could be defined. This includes how predicted future abiotic stresses could not only pre-dispose some species to more severe disease infections but also how they alter both pathogen diversity and expression of host resistances to diseases. Subsequently, the potential impacts of changing *Brassica* crop species on other components of cropping systems across different countries representing

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different current and future climate scenarios could be defined. Using oilseed Brassicas as model species will not only define the potential hazards involved in simply shifting crop species initially to overcome abiotic limitations imposed by climate change, but will actually define the basis for capturing the benefits and opportunities these alternative *Brassica* species offer as a means of coping with climate change. In this way, oilseed Brassicas could be utilized to define pre-emptive management strategies, such as by breeding for better and/more appropriate types and levels of host resistance to pathogens and deploying host resistances in better and more controlled ways to maximize the longevity of such host resistance in the face of changing pathogen pathotypes. This review will utilize the outcomes of studies in relation to pathogens, particularly pathogen biodiversity, and diseases of oilseed Brassicas over past decades as a basis for outlining the challenges, opportunities and priorities for improving on current management successes such that crop yields can be maintained in the face of expected pathogen threats likely to occur under future climate scenarios.

Contents

1. Introduction

Around the world climate change is both affecting agricultural and horticultural crops (Metz et al., 2007; Stern, 2007) and the diseases that affect them (Chakraborty, 2005; Garrett et al., 2006). The influence of climate change on plant pathogens and their consequent diseases has been well reviewed over the past two decades (e.g., Prestidge and Pottinger, 1990; Atkinson, 1993; Manning and Tiedemann, 1995; Coakley, 1995; Coakley and Scherm, 1996; Chakraborty et al., 1998, 2000b; Chakraborty, 2005). It has been stated that climate change may reduce, increase or have no effect on individual plant diseases (Chakraborty et al., 1998). The different individual parameters associated with climate change, such as warmer temperatures, increased levels of CO_2, decreased rainfall and increased rainfall variability, have all been studied in terms of their influence on different aspects of pathogens and diseases across various crops (Chakraborty, 2005). These include pathogen life cycle (e.g., Chakraborty et al., 2000a; Chakraborty and Datta, 2003), expression of host resistance (e.g., Hartley et al., 2000; Chakraborty and Datta, 2003), disease epidemiology and severity of disease epidemics (e.g., Pangga et al., 2004; Evans et al., 2008; Butterworth et al., 2010), and pathogen inoculum production (e.g., Chakraborty et al., 2000a). Changes associated with climate change not only have direct effects on the ability of the crop (host) to yield and on behaviour of the pathogens, but can also affect the pathogen–host interactions at all levels (e.g., Eastburn et al., 2010; Newton et al., 2010a).

Climate change is creating food security problems associated with crop diseases (Strange and Scott, 2005) and threatens to make food shortages more acute (Anderson et al., 2004; Chakraborty et al., 2000b; Garrett et al., 2006; Gregory et al., 2009; Stern, 2007). This is particularly true for farmers in more marginal regions (Schmidhuber and Tubiello, 2007).

This paper reviews the effects of climate change on pathogen biodiversity and pathogen threats, using fungal and oomycete pathogens and diseases in oilseed Brassicas as a model case study. It includes comparisons to other pathogen–crop combinations as appropriate. It is not the intention of this review to repeat coverage given in previous reviews as listed above relating to various aspects of climate change and pathogens. Instead, the outcomes of studies in relation to pathogens, particularly pathogen biodiversity, and diseases of oilseed Brassicas over past decades will be used as a basis for outlining the challenges, opportunities and priorities for improving on current management successes such that crop yields can be maintained in the face of expected pathogen threats likely to occur under future climate scenarios.

2. Climate change and oilseed Brassicas

The genus *Brassica* is a diverse collection of agriculturally and horticulturally important species (Dixon, 2007; Warwick et al., 2009), and includes some widely cultivated oilseed species, such as *Brassica napus* (rapeseed), *Brassica rapa* (turnip rape; syn. *Brassica campestris*), *Brassica juncea* (Indian mustard), and *Brassica carinata* (Abyssinian/Ethiopian mustard) (Rich, 1991; Dixon, 2007; Snowdon et al., 2007; Warwick et al., 2009). In recent decades, oilseed rape (mainly *B. napus* and *B. rapa*) has become the second most important oilseed crop worldwide (Snowdon et al., 2007). This rapid advance in production is largely attributed to breeding for reductions in erucic acid and glucosinolate content, greatly improving its worth as edible oil for human consumption and as a livestock feed, respectively (Snowdon et al., 2007).

With the advent of climate change, as with most crops, oilseed Brassicas are facing more variable climates, including higher and