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Disease control on UK winter oilseed rape contributes to climate change mitigation

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Abstract

The UK government has published plans to reduce UK agriculture's greenhouse gas (GHG) emissions. At the same time, the goal of food security requires an increase in arable crop yields. Foliar disease control measures such as fungicides have an important role in meeting both objectives. As an example, it is estimated that production of UK winter oilseed rape is associated with GHG of 3337 kg CO_2 eq ha^{-1} of crop and 834 kg CO_2 eq. t^{-1} of seed yield, with 79% of the GHG associated with the use of nitrogen fertiliser and only 0.3% of the GHG associated with fungicides, herbicides and insecticides. Furthermore, it is estimated that control of diseases by use of fungicides in this UK oilseed rape is associated with a decrease in GHG of 100 kg CO_2 eq. t^{-1} of seed. Winter oilseed rape cultivar resistance against the pathogens *P. brassicae* and *L. maculans* is associated with decreases in GHG of 32 and 24 kg CO_2 eq. t^{-1}, respectively, although these figures are probably underestimates. Similar work has been done with winter wheat, winter barley and spring barley. Fungicide treatment of these four UK arable crops is estimated to have directly decreased UK GHG emissions by over 1.6 Mt CO_2 eq. in 2009. These results demonstrate how disease control in arable crops can make an important contribution to climate change mitigation now. There is an urgent need to develop integrated strategies for disease control to sustain arable crop production and ensure global food security, whilst minimising greenhouse gas emissions.

Key words: adaptation to climate change, disease resistance, food security, fungicides, greenhouse gas emissions, oilseed rape, sustainable agriculture

Introduction

Crop diseases directly threaten global food security because diseases are causing crop losses, estimated at 16% globally, despite efforts to control the diseases (Oerke, 2006), in a world where more than 1 billion people (one sixth of world population) do not have enough food to eat (Anonymous, 2009). Thus, food production must be increased by controlling crop diseases more effectively. If crop losses to pests and diseases were decreased by 1% worldwide, then an estimated extra 25 million people could be fed with no extra use of land, water, fertilisers or chemicals (CABI report, 2009-2010; http://www.cabi.org/). By contrast, if factors such as climate change increase losses from crop diseases, more people will go hungry.

Since the threats of climate change to food security are particularly severe in marginal areas, there is pressure on farmers in areas that may benefit from climate change, such as northern Europe (Butterworth *et al*., 2010), to produce more food to ensure global food security. It is therefore essential to include methods to control disease problems in development of strategies for adaptation to the impacts of climate change. However, it is also necessary to grow crops in countries such as the UK in a manner that decreases emissions of greenhouse gases (GHG) to contribute to climate change mitigation from agriculture. The options for decreasing the contribution of agriculture to global warming include decreasing the use of fossil fuels and nitrogen fertilisers, decreasing methane emissions from livestock and increasing the sequestering of carbon from the atmosphere.

Whilst the consequences of climate change for food security due to sea-level rise, desertification, drought and heat-stress are widely recognised (FAO Food Security, 2009; http://www.fao.org), the importance of including crop diseases in climate change impact assessments is not. This paper reports work to study the contribution to climate change mitigation from disease control in arable crops through fungicide treatment, using UK oilseed rape as an example. These results are combined with those from similar studies for other crops to estimate the impact of disease control on GHG emissions and arable crop area for the main UK arable crops.

GHG emissions associated with crops with or without disease control

It is estimated that production of UK winter oilseed rape is associated with GHG of 3337 kg CO_2 eq. ha^{-1}, with 79% of the GHG associated with the use of nitrogen fertiliser and only 0.3% of the GHG associated with fungicides, herbicides and insecticides (Mahmuti *et al*., 2009). Differences in yields between fungicide-treated and untreated plots in experiments throughout the UK were analysed to estimate effects of fungicides to control disease on the GHG emissions per tonne of seed. The GHG emissions per tonne of winter oilseed rape seed produced were estimated at 834 kg CO_2 eq. The GHG emissions per tonne of seed produced decreased as the yield of the seed increased; the difference in GHG emissions t^{-1} between yields of 1 and 3 t ha^{-1} was 2225 kg CO_2 eq. t^{-1}. In one series of trials in England and Scotland with 627 units of yield data during 2004-2007, mean yields were 4.33 t ha^{-1} for fungicide-treated and 3.84 t ha^{-1} for untreated crops. The disease-induced yield loss of approximately 11.3% of the fungicide-treated winter oilseed rape yield was associated with a net increase in emissions of 98 kg CO_2 eq. t^{-1} for winter oilseed rape produced without fungicide treatments by comparison to fungicide-treated crops (Figure 1). The annual mean differences in GHG emissions from other series of trials ranged from 82 kg CO_2 eq. t^{-1} to 169 kg CO_2 eq. t^{-1} (Mahmuti *et al*., 2009).

There were yield differences between resistant and susceptible cultivars in all trials. In trials during 2004-2007, cultivars susceptible to *P. brassicae* on average yielded 4.43 t ha^{-1} while resistant cultivars yielded 4.63 t ha^{-1}. This disease-induced yield loss from using cultivars susceptible to *P. brassicae* of 0.2 t ha^{-1} (4.3%) was equivalent to a difference in emissions between susceptible (753 kg CO_2 eq. t^{-1}) and resistant (721 kg CO_2 eq. t^{-1}) cultivars, with a net saving of 32 kg CO_2 eq. t^{-1} from growing resistant cultivars. For *L. maculans* (phoma stem canker), the mean yields were 3.84 t ha^{-1} and 3.95 t ha^{-1} for susceptible and resistant cultivars, respectively. Thus the yield loss for cultivars susceptible to *L. maculans* averaged at 0.11 t ha^{-1} (2.8%). These yields were equivalent to emissions of 869 kg CO2 eq. t^{-1} and 845 kg CO2 eq. t^{-1}, with a net benefit of 24 kg CO_2 eq. t^{-1} from growing resistant cultivars.

Use of these yield differences between resistant and susceptible cultivars to estimate effects of resistance on GHG emissions greatly underestimated the effects of disease resistance, since yield differences between cultivars can be attributed to many different factors, including the differences in yield potential between cultivars, susceptibility of cultivars to other pathogens and the regional adaptation of cultivars to locations of the experiments. Although such factors probably minimised the effects that resistance had on yield loss, the resistant cultivars still yielded more and were associated with less GHG emissions than susceptible cultivars, irrespective of these factors.

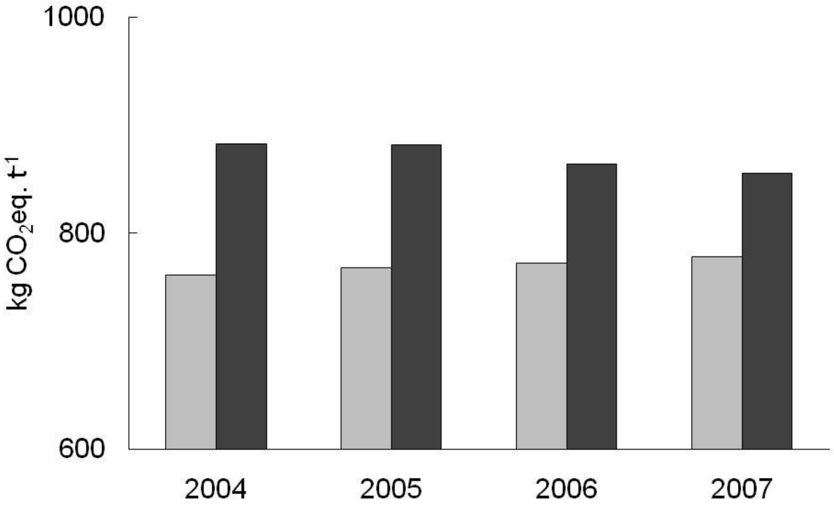

Fig. 1. Differences in greenhouse gas (GHG) emissions per tonne of yield between winter oilseed rape crops (means of 24-39 cultivars at 4-7 different sites) treated with fungicides to control phoma stem canker and light leaf spot diseases (■) and untreated crops (■) in the HGCA trials, at sites differing in epidemic severity. The numbers of sites where the data were available for both treated and untreated crops were 5 (2004), 7 (2005), 6 (2006) and 4 (2007). The numbers of cultivars used in different years were 26 (2004), 39 (2005), 24 (2006) and 29 (2007). Adapted from Mahmuti *et al*. (2009).

Similar calculations have been done for UK winter barley and spring barley and UK winter wheat. In UK winter barley, fungicide treatment reduced GHG emissions by 42 - 60 kg CO_2 eq. t^{-1} (11-16%) and for spring barley, fungicide treatment reduced GHG emissions by 29 - 39 kg CO_2 eq. t^{-1} (8-11%) (Hughes *et al*., 2011). Disease control in winter wheat reduced GHG emissions by 60kg CO_2 eq.t^{-1} (Berry *et al*., 2008). However, these calculations all underestimate the climate change mitigation benefits of disease control since the fungicide treatments did not completely control diseases. In addition, disease epidemics can be much more severe than those in trials.

Wheat, oilseed rape and barley currently represent over 95% of UK arable crops by area. If it is assumed that UK crops are treated with fungicides and that the potential percentage yield losses from disease in these crops are those observed in trials, it is possible to estimate that fungicide treatment reduced UK GHG emissions by 1.64 Mt CO_2 for the four major UK arable crops (winter barley, spring barley, winter wheat, and winter oilseed rape) in 2009. There continue to be reductions in GHG emissions under a wide range of alternative assumptions for the emission factors of agricultural inputs (Hughes *et al*., 2011).

Discussion

These results demonstrate that disease control in arable crops can contribute now to targets for climate change mitigation by decreasing GHG emissions. Disease control through improved disease resistance and more accurate fungicide timing should be included in policy options for decreasing GHG emissions from agriculture (Smith *et al*., 2008). Controlling crop diseases gives benefits not only in terms of decreased GHG per tonne of crop produced but also in increased yield to increase food production in northern Europe in response to climate change threats to food security in other regions. These decreases in GHG are especially associated with more efficient use of nitrogen fertiliser applied to the crop. When added together, disease control in UK arable crops can make a substantial contribution to government targets for decreasing GHG emissions from agriculture (Hughes *et al*., 2011). It is also likely that there will be climate change mitigation benefits from disease control in other arable crops in different regions of the world, especially where inorganic or organic nitrogen fertilisers are used to increase yields. It is environmentally preferable to increase food production by decreasing losses to diseases rather than by expanding the area cultivated with crops. The latter will require conversion or destruction of other natural ecosystems, resulting in further increases in GHG emissions.

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