Impact of Climate Change on the Occurrence and Activity of Harmful Organisms

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Abstract: Climate conditions exert a significant influence over the spreading, life cycle duration, infestation pressure and the overall occurrence of majority of agricultural pests and diseases. Recently there is paid a big attention to possible climate change and its impacts resulting the threat to the controlled agro ecosystems. In the context of actual climate change there is likely the shift in the occurrence of some pests and diseases and at the same time also the change of the spectrum of harmful organisms. Direct results of the effect of higher temperatures on the pests' lifecycle can involve the acceleration of pests' development due to the faster achieving of number of degree-days which can result the shift of pests to higher altitudes. There is likely the increase of the number of generations of some pests and higher population density in the consequence of prolonged growing season and the period favourable for reproduction. Changed conditions during the period of overwintering could be the determining factor for population dynamic of insect and fungi.

Keywords: climate change impacts; pests; diseases; temperature; precipitation

There is a number of factors determining the occurrence and abundance of harmful organisms in agro ecosystems, e.g. the presence of host plants, the effect of agronomical practices or control measures. The next important factors are both climate conditions of the location and the course of weather within the given season. Recently a great attention has been paid to a possible climate change and its impacts resulting in the threat to the controlled agro ecosystems (IPCC 2007). In context of the actual climate change, there is likely to be a shift in the occurrence of some weather depending pests and diseases and at the same time also the change of the spectrum of harmful organisms.

Climate change impact on the pests occurrence

Changes in climate may result in changes in geographical distribution of species, changes in population growth rates, increases in the number of generations, extension of the growing season, changes in crop-pest synchrony, changes in interspecific interactions and increased risk of invasion by migrant pests (Porter *et al.* 1991).

Insects are exothermic organisms, the temperature of their bodies is dependent on that of the environment. Therefore, temperature is probably the single most important environmental factor

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influencing insect behaviour, distribution, development, survival, and reproduction.

Higher average temperature might result in some crops being able to be grown in regions further north – it is likely that at least some of the insect pests of those crops will follow the expanded crop areas. Insect species diversity per area tends to decrease with higher latitude and altitude (Gaston & Williams 1996; Andrew & Hughes 2005), meaning that rising temperatures could result in more insect species attacking hosts in temperate climates. Based on the evidence developed by studying the fossil record, some researchers (Bale *et al.* 2002) conclude that the diversity of insect species and the intensity of their feeding have increased historically with increasing temperature.

There is likely to be an increase of the number of generations of pests and higher population density in connection with the prolonged growing season. An increase in the number of generations means an increase in the number of reproductive occasions per year. It has been estimated that with a 2°C temperature increase in temperate climate zones insects might experience one to five additional life cycles per season (Yamamura & Kiritani 1998). If the mortality per generation does not change, the insect population will become potentially larger under global warming (Yamamura & Yokozawa 2002). This fact could play an important role in the case of multivoltine species, most of them are expected to wider their occurrence to higher latitudes and altitudes as was recorded e.g. in many cases of butterflies (Pollard *et al.* 1995; Hill *et al.* 1999; Parmesan *et al.* 1999). Warmer conditions may be expected to promote the poleward extension of the range of species currently limited by low temperature or the altitude at which they can survive. A 2°C rise in temperature, which is expected in northern temperate latitudes over the next century, is equivalent to a shift of current conditions of 600 km latitude or 330 m in elevation. Some researchers declare that the effect of temperature on insects largely overhangs the effects of other environmental factors (Bale *et al.* 2002).

Insect life stage predictions are most often calculated using accumulated degree days from a base temperature. Climate matching is a common model tool for the estimates of the impact of climate change on the species' extension. Climate matching identifies extralimital destinations that could be colonised by a potential invasive species on the basis of similarity to climates found in the species' native range (Rodda *et al.* 2007). Model validation is carried out by comparing modelled and observed current pest's occurrence, obtained from field observations. The model of the potential species extension in expected climate conditions is prepared by the modification of the current climate data according to the estimates of the GCM models (Global circulation models) (e.g. ECHAM, NCAR and HadCM) and SRES emission scenarios (e.g. A2, B1, A1T) expressing the climate sensitivity to rising CO_2 concentrations. A number of studies considering the climate change impact on various organisms. For instance, according to one of the first studies focused on the impact of climate change on European corn borer (*Ostrinia nubilalis* Hübner 1796) populations in Europe (Porter *et al.* 1991), a temperature increase associated with ongoing climate change would lead to the shift of the ECB occurrence area to the north and possibly to the occurrence of the second generation in the presently univoltine areas.

Other studies assess the climate change impacts on selected pests especially on the most important potato pest, i.e. Colorado potato beetle (*Leptinotarsa decemlineata* Say 1824) and the most important pest of grain maize, i.e. European corn borer (*Ostrinia nubilalis* Hübner 1796) in the Czech Republic (Trnka *et al.* 2007; Kocmánková *et al.* 2008). These two species are expected to wider their occurrence area and increase the infestation pressure due to the climate change. The development of these species is closely related to climate conditions and mainly to the course of temperature. Mechanisms by which climate conditions affect the species development were analysed with the usage of the Australian program CLIMEX. This program allows the estimation of climate limits for population growth of pests based on their current geographical distribution. In current climate conditions European corn borer (ECB) has first generation with exceptional occurrence of the second generation in neighbouring Slovakia only in unusually warm growing seasons. CLIMEX estimates that during the next 25 years ECB could potentially become established as a significant maize pest in large numbers throughout the whole area of the Czech Republic with two generations in the main production regions which compose 38% of arable land and possible one generation in areas above 800 metres a.s.l. Results were supported by the estimates of the sophisticated semi-quantitative model ECAMON (Trnka *et al*. 2007). CLIMEX was used also for the simulation of Colorado potato beetle (CPB) occurrence, CPB in the current climate conditions of CR develops 1–2 generations. Model of the expected climate according to the combination of selected GCM and emission scenario means almost the half of the arable land endangered by the occurrence of two generations by 2025. The same model indicates that for 2050 this area increases by 72%. Based on the simulation results there is an apparent risk of the increasing damage caused by both pests due to the shifts in the climate conditions. Widening of the CPB's area in the conditions of climate change confirmed also Baker *et al.* (2000) in the CLIMEX simulation of the climate suitability assessment in GB and Europe. These results suggest that global change would provide mean northerly increase of 3.5° latitude (400 km) and the greatest increases in suitability for Colorado beetle lie between latitudes 50°N and 65°N in northern Europe. Simulations of the occurrence of the CPB as the exotic pest in Norway made by Raffos and Sæthre (2003) indicated current climate as not suitable for long-term establishment of the species. The climate change scenarios clearly indicated that a temperature increase could provide a shift in the establishment conditions from non-favourable to favourable for *L. decemlineata* at several locations.

Climate change impact on the occurrence and activity of disseases

The three legs of the triangle – host, pathogen, and environment – must be present and interact appropriately for a plant disease to result. If any of the 3 factors is altered, changes in the progression of a disease epidemic can occur. The major predicted results of climate change – increased temperature, moisture and CO_2 – can impact all three legs of the plant disease triangle in various ways (Coakley *et al.* 1999). Temperature governs the rate of reproduction for many pathogens, longer seasons that result from higher temperatures will allow more time for pathogen development. Pathogen development may also be more rapid when large pathogen populations are present, so increased overwintering and oversummering rates will also contribute. Under climate change, pathogens, like plants, may potentially be unable to migrate or adapt as rapidly as environmental conditions change. But most pathogens will have the advantage over plants because of their shorter generation times and the ability to move readily through wind dispersal.

Research has shown that host plants such as wheat and oats become more susceptible to rust diseases with increased temperature (Coakley *et al*. 1999). Generally, fungi that cause plant disease grow best in moderate temperature ranges. For example, predictive models for potato late blight (caused by *Phytophthora infestans*) show that the fungus infects and reproduces most successfully during periods of high moisture that occur when temperatures are between 7.2°C and 26.8°C (Wallin & Waggoner 1950). Earlier onset of warm temperatures could result in an earlier threat from Potato late blight (PLB) with the potential for more severe epidemics and increases in the number of fungicide applications needed for control.

The next factor increased CO_2 levels can impact both the host and the pathogen in multiple ways. Some of the observed CO_2 effects on disease may counteract others. Researchers have shown that higher growth rates of leaves and stems observed for plants grown under high CO_2 concentrations may result in denser canopies with higher humidity that favour pathogens (Coakley *et al*. 1999). In general, increased plant density will tend to increase leaf surface wetness and leaf surface wetness duration, and so make infection by foliar pathogens more likely (Huber & Gillespie 1992). Lower plant decomposition rates observed in high CO_2 situations could increase the crop residue on which disease organisms can overwinter, resulting in higher inoculum levels at the beginning of the growing season, and earlier and faster disease epidemics. Pathogen growth can be affected by higher CO_2 concentrations resulting in greater fungal spore production. However, increased CO_2 can result in physiological changes to the host plant that can increase host resistance to pathogens. Fungicide and bactericide efficacy may change with increased CO_2, moisture, and temperature. The more frequent rainfall events predicted by climate change models could result in farmers finding it difficult to keep residues of contact fungicides on plants, triggering more frequent applications. From the above-mentioned circumstances there is likely to be the risk of the affecting of diseases occurrence in various ways: (a) winter temperatures will probably be the cause of the survival of higher populations of pathogens; b) increased temperatures will probably result in northward expansion of the range of some diseases because of earlier appearance and more generations of pathogens per season; c) more frequent or more intense rainfall events will tend to favour some types of pathogens over others (Coakley *et al*. 1999).

Many mathematical models that have been useful for forecasting plant disease epidemics are based on increases in pathogen growth and infection within specified temperature ranges. In the study of Kocmánková *et al*. (2007) there was developed a model allowing the assessment of the risk of the early outbreaks or increases in the intensity of Potato late blight (*Phytophthora infestans*) under the climate change. As a tool for the assessment of the PLB outbreak date and the number of infectious days it was decided to implement the DYMEX model building tool. In the framework of DYMEX a PLB model was developed, calibrated and validated using observed data. Then the present climate data were perturbed by the climate change scenarios for the periods 2020 and 2050. Under all climate change scenarios there was noted a marked change in the infestation pressure of evaluated disease and the higher number of favourable days for PLB outbreak. The number of hours with favourable conditions which are necessary for the outbreak of infection corresponds to the scenarios achieved earlier, especially the occurrence of these days in May constitutes a significant treat for the potato yields. Similar results were indicated in the study of Žalud *et al*. (2008) where weather driven NegFry model has been used for estimating future PLB occurrence at four experimental potato stations of the State Institute for Agriculture Supervision and Testing. Both the infestation dates of PLB occurrence and the shape of the critical number curve were analysed using observed weather data as well as data sets constructed according to four climate change scenarios that were based on two global circulation models. The results show the shift of the infestation pressure to the beginning of the year and describe an increasing trend of critical number reaching to the detecting of the first *Phytophthora infestans* occurrence for 2025 and 2050. It is necessary to emphasise the study of Chakraborty *et al.* (2000) which suggests that the most likely impact of climate change will be felt in three areas: in losses from plant diseases, in the efficacy of disease management strategies and in the geographical distribution of plant diseases. Authors also mean that improvements in methodology are necessary to realistically assess disease impacts at a global scale. The risk of damage from late blight of potato would increase in all regions, pathogen would follow migrating host plants and their dispersal and survival between seasons and changes in host physiology and ecology in the new environment would largely determine how rapidly the pathogens establish in the new environment.

CONCLUSION

It is not precisely understood how the climate change will affect crops, insects, diseases, and the relationships among them. The precise impacts of climate change on insects and diseases are somewhat uncertain because climate change may favour some pathogens and insects while it may inhibit others. The preponderance of evidence indicates that there will be an overall increase in the number of outbreaks of a wider variety of insects and pathogens. New pests are likely to become established in more northerly areas and to be able to attack plants in new regions. Plants in some regions are likely to be attacked more frequently by certain pests. Mentioned facts can have the direct impact on the increase of damages caused by pests and diseases, this will to the contrary have the impact in the costs of protective treatments in relation to these organisms. The best economic strategy for farmers to follow is to use integrated pest management practices to closely monitor insect and disease occurrence.

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