Quantification of climate change impacts on agricultural pests

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Abstract:

Temperature is the dominant abiotic factor determining development rates, preproduction and migration of many insects. Climate change will therefore alter population abundance, geographical distribution and seasonal phenology of important agricultural pests. Scenarios concerning possible impacts of climate change on pests are necessary to identify adapted plant protection strategies and sustainable plant management options. Model-based studies are a valuable method for estimating the impacts of climate change on insect pests. Such projections are not easy to develop, because impact models often require a high temporal and spatial resolution of future climate data and long-term field observations are necessary for model calibration and validation.

Over the last decades impact studies have been aided by advances in climate modelling. For instance, the Swiss climate research network produced regional and localized climate change scenario information that provide an unprecedented opportunity for the impact modelling community in terms of spatial resolution. Nevertheless, the question of how to estimate the impact of climate change on pests across spatial and temporal scales remains open. In this contribution, we will discuss different issues related to impact modelling and its application to climate change adaptation at the example of a key apple fruit pest, the codling moth (*Cydia pomonella* L.).

The degree-days approach is the standard method to simulate phenological development of insects: it represents the accumulation of heat units above a minimum temperature threshold as required for an organism to develop from one stage to another in its life cycle. Most phenological models utilize daily mean air temperatures on input and hence do not take into account daily temperature fluctuations. A comparison with models that run at the hourly scale indicates that the differences are sometimes important, depending on the degree-days parameters (e.g. temperature threshold).

More complex models use linear and non-linear functions to model the relationship between temperature and stage specific development rates and also consider microhabitat temperature. The codling moth seasonal phenology model implemented in SOPRA, a decision support system available to Swiss producers, is based on time-varying distributed delay routines that operate at the hourly scale and simulates the proportion of life stages in the population with a temporal resolution of one day in the output. Due to the distributed delay approach, life stages are fully overlapping. Relative phenology is provided as a measure of population abundance. In one of our studies, the model was used to assess the occurrence of the codling moth under future climatic conditions, using site-specific climate change scenarios. The results showed significant shifts to earlier dates in codling moth phenological events, increased magnitude of the 2nd generation, less overlap between stages and a bigger risk for an additional 3rd generation under future climate conditions. These results will be discussed in terms of seasonal and long-term forecasts and plant protection strategies.

The codling moth has a facultative diapause. Photoperiod (length of day) is the genetically controlled signal for regulation of the diapause induction. Shifts in phenology may induce an evolutionary response toward shorter photoperiods (delayed diapause induction) that would thereby even more increase the risk of additional generations. The sensitivity of relevant phenological events to an evolutionary shift in diapause induction to shorter photoperiod and implications for the date of the diapause induction under future climate scenarios will be discussed.

Besides direct effects on pests, climate change will modify plant-pest-natural enemy interactions. Simulating the temporal synchrony between host-plant and pest phenology is complex und uncertain. Here we discuss a simplified heating model for apple flowering based on temperature sums at hourly scale. This model is easily applicable in climate change scenarios to project the shift in synchrony between apple flowering termination and codling moth larval emergence start. Flowering termination is taken as a proxy for host (apple fruit) presence.

Finally we consider research needs to improve assessments of climate change impacts on agricultural pests. Among other issues we address the needs for: (i) information about relevant species traits increasing the sensitivity of the species to climate change; (ii) improved knowledge on non-seasonal mortality, indirect effects of climate change and interactions (i.e. drought and pest); (iii) improved knowledge concerning the effectiveness of predators and parasitoids under changing climate to model complex trophic interactions; (iv) coupling pest models with crop suitability models and ecological niche models, a step required to obtain a comprehensive risk analysis.

Key words: climate change, impact modelling, insect pests, plant protection strategy