CLIMATE AND PLANT PATHOGENS

A CASE-STUDY ON GRAPEVINE

*Climate change has an impact on the whole agro-ecosystem. This study shows the possible final effect of climate change on the interaction between the host-plant development and its major pest (*Lobesia botrana*) and pathogen (*powdery mildew*) in Trentino (Italy).*

1. Climate changes and plant pathogens

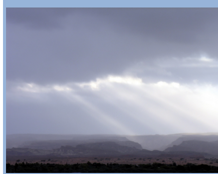
In the next decades major shifts in temperature and changes in the seasonal pattern of rainfall distribution are expected in most of the world. Climatic projections suggest that these trends will continue in the coming decades, affecting both mean and extreme values of these variables.

In the latest report of the Intergovernmental Panel on Climate Change (IPCC), mean global temperature is estimated to increase between 1.8 and 4.0 °C (with a likely range of 1.1 to 6.4 °C), by the end of the present century, depending on the greenhouse gas emission scenarios.

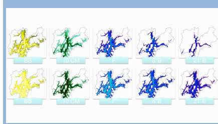
The combination of climate change, associated disturbances and other global change drivers is expected to exceed the resilience of many agro-ecosystems. As a consequence, global warming could

Key-features

The biology of pest and diseases are interdependent with their host plant. A change of climate influences the complexity of the whole interaction.



In presence of pests and pathogens, their attacks or infections occur only under specific environmental conditions and only if the host plant is at susceptible growth stage.



This studied system shows a high complexity. One of the aims of Envirochange was to disentangle it by using a combination of models.

Results show that, while higher temperatures might favour the development of certain pests, they could also shorten the length of crop cycles, thus balancing out a potential increase in pest pressure.

In particular:

- while increased temperature resulted in an increase in the number of generations of *Lobesia botrana*, grapevine phenology was accelerated thus the new generation occurs when berries are already harversted;
- climate warming might decrease the severity of powdery mildew infections, especially on extreme years with particularly high temperatures.

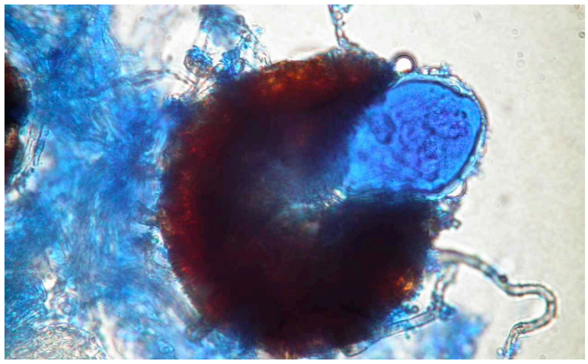
substantially impact agriculture and food production. The result of this climatic change should not be always seen as a threat to farm productivity, especially where water is not a limiting factor; however, the perceived outcomes of climate change expected by European farmers remain mostly negative, and in particular, there is a feeling that the risk from pests for grapevine will increase in the alpine region.

However, consequences of climate-driven changes are not easily predictable in complex agro-ecosystems, as the biology of pests (hereinafter, this term is used to define both arthropods and plant disease agents) and that of their host plant are interdependent.

For example, many pests attack their host plant only during specific vulnerable periods of the plant life-cycle. This is the case of the pests that infect plants through their flowers, as the bacterium *Erwinia amylovora*, which can penetrate its hosts (e.g., apple and pear) during flowering.

Other pests might be able to attack their host all along their growth season but cause higher damage during specific growth stages. For example, the larvae of European grapevine moth (*Lobesia botrana*) are less harmful during flowering and produce more damage in the post-veraison period, when they favour gray mould (*Botrytis cinerea)* infections. Many plant species progressively increase their resistance to pests as they age by developing "ontogenic" resistance, which may be active on the whole plant or in specific organs or tissues. For example, grape berries are reported to be susceptible to *Erysiphe necator* (the powdery mildew fungus) infections until soluble solids levels reach 8% (8 °Brix), and the established fungal colonies are reported to sporulate until soluble solids levels reach 15% (15 °Brix).

Lobesia botrana (courtesy Gianfranco Anfora)



Ascospores released from a *Erysiphe necator* chasmothecia

Grey mould caused by *Botritis cinerea*

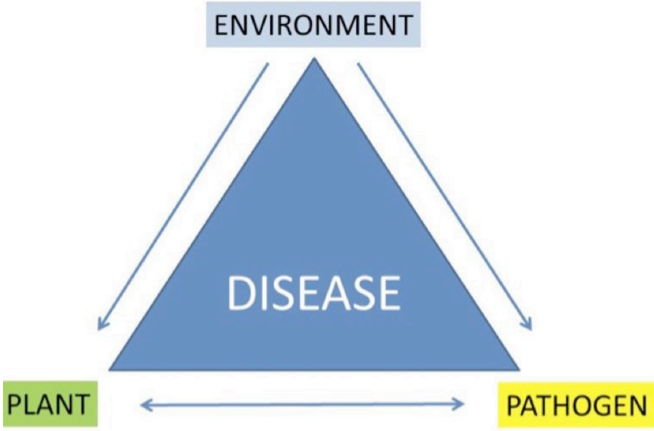
***Ontogenic resistance**: ontogenic resistance is the capability of plants to defend themselves in different stages of their development. I.e. older leaves are more robust and generally have an increase in chemical and physical defences to pathogen invasion.*

***Powdery mildew:** is a disease affecting different plants. It is caused by different species belonging to the order Erysiphales. Disease sympoms are white powdery spots on the leaves, flowers, young fruits and stems.*

Thus, in presence of pests, attacks will occur only under specific environmental conditions and only if the host plant is in a susceptible growth stage. For pathogens, this interaction has been frequently represented by the "plant - disease triangle", which is made up by the three elements required for the infection to develop: a susceptible host, the presence of the pathogen, and a conducive environment.

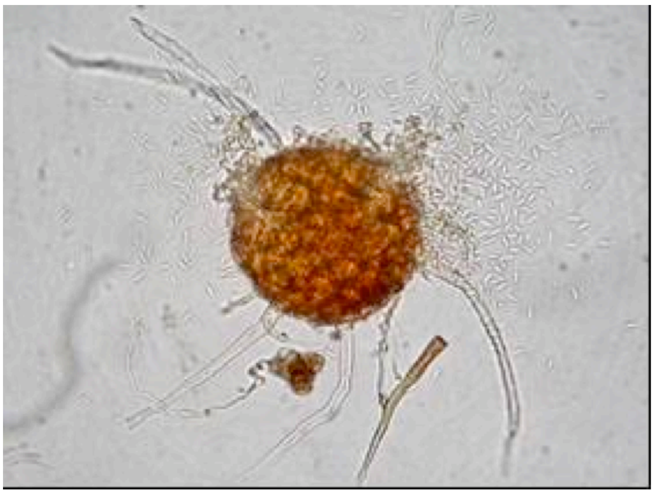
In addition to the above described "susceptibility windows", one should consider the duration of the productive cycle of each crop. In fact, while higher temperatures might favour the development of certain pests, they could also shorten the length of crop cycles, thus balancing out a potential increase in pest pressure. For example, higher temperatures might cause an increase in the number of generations of insect species that are able to produce several broods per year (multivoltine species). This would imply an increase in the number of reproductive events per year, leading to an increase in population, and increased levels of infestation. However, if the last generations emerged after crop harvest, it would not impact on crop yield, and pest population might decrease in size due to the absence of suitable food.

While it is clear that all these factors respond to climatic variables, they might be controlled by different combinations of driving factors, or respond to their change at different rates. In order to disentangle these effects, we need to improve our understanding of the host-pest system. Indeed, meaningful projections of climate change impacts on disease/infestation pressure can be obtained only by coupling host phenology with patterns of pest development and attack. At present, only a few modelling studies have considered these interactions for the projection of climate change impacts on agriculture. In fact, most works have concentrated on the effects of climate change on either the physiology/phenology of single crops.



The 'triangle' of the disease


Vineyard in summer in Trentino (Italy)


Powdery mildew chasmothecia parasitized by *Ampelomyces quisqualis* conidia (courtesty Dario Angeli)

Crop phenology

Phenology is the science that studies the occurrence of the vegetative and reproductive stages in plant and animal life cycles. A typical investigation is the creation of mathematical models that simulate the timing of crop annual cycles as a function of the meteorological drivers (mainly temperature).

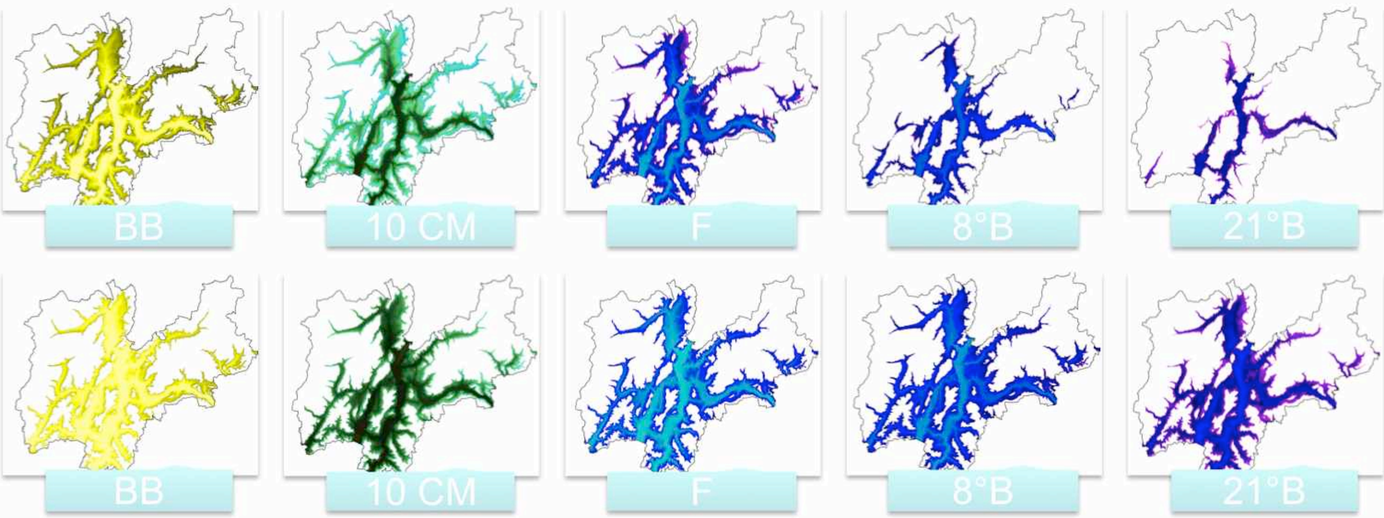
2. Grapevine

During 2009 we monitored the phenology of grapevine through extensive field surveys with the aim of refining existing phenological models of this crop.

While current phenological models of crops only take into account phenophases useful for planning agricultural practices (such as flowering and ripening), in order to evaluate potential changes to the risk of attack by pests and diseases, "vulnerable" phenophases also need to be considered. Data were collected from five important grapevine varieties for Trentino viticulture, comprising three white (Chardonnay, Pinot gris and Sauvignon blanc) and two black varieties (Pinot noir and Merlot), and these were used to refine an existing phenological model (the FENOVITIS model, originally developed for the simulation of budburst, flowering and veraison).

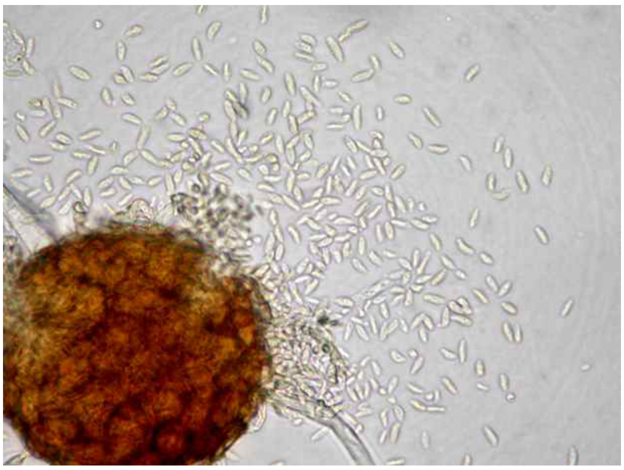
The model was extended by calibrating and integrating two new phenological phases into it, that define the vulnerability window to *Botrytis cinerea* and *Erysiphe necator*. Existing disease risk models for *E. necator* and the *Lobesia botrana* development model were validated with data from Trentino and applied to climate change scenarios, to obtain projections of climate change.

Chardonnay – 2000/2010



Phenological stages of grapevine calculated at specific times of the year, in 2000 (top) and in 2010 (bottom).

Lobesia botrana (chrysalis) (Courtesy Gianfranco Anfora)



Powdery mildew chasmothecia parasitized by *Ampelomyces quisqualis* conidia (courtesty Dario Angeli)

2.1 Grapevine moth

In our projections rising temperatures resulted in a marked increase in the mean number of generations completed by this moth. However, when we considered the number of pre-harvest larval generations as opposed to the total number of larval generations, the increasing trend was not so pronounced. In fact, while the simulation of the total number of generations within a year was driven only by temperature and photoperiod, simulation of pre-harvest generations also depended on harvest time, which was in turn dependent on temperature during ripening. Increasing temperatures resulted in a marked advance in simulated harvest dates, but did not alter the timing of diapause induction, which is controlled by photoperiod. These results suggest that for Chardonnay, a potential increase in the pressure by European grapevine moth may be balanced by an earlier harvest and less time for larvae to produce damage.

IOn the other hand, in viticultural areas where late and early varieties are grown, this might lead to a higher pressure on late than early ripening varieties. The projection of the timing of resistant plant growth stages in conjunction with the occurrence of first generation larvae made it possible to assess current and future patterns of plant-pest interaction. According to the simulations, currently, at all sites and for all scenarios there is a considerable temporal overlap between larvae and the flowering - fruit set window in Chardonnay. These results find support in the field observations from the study area. However, this overlap might decrease in the future at warmer, low elevation sites. In fact, while increased temperature resulted in a significantly earlier moth phenology, it advanced grapevine phenology to a lesser extent, resulting in a decrease in the synchrony between larvae and resistant phenology.

Lobesia botrana **(courtesy Gianfranco Anfora)**

2.2 Powdery mildew

Vineyard in early spring

For powdery mildew, simulations showed a decrease in simulated disease severity especially in years with a later onset of the epidemics (assuming a low-intermediate disease pressure) and in the climate scenario of higher temperature increase. In particular, there was a more pronounced decrease in the mean number of infection cycles at low elevation sites, which is likely to be due to the fact that powdery mildew development has an optimal development temperature between 22 and 27°C. As the climate of low elevation sites is currently in this optimal temperature range during the susceptible period of grapevine (spring-summer) a temperature increase would inevitably increase the latency duration.

These results suggest that climate warming might decrease the severity of powdery mildew infections, especially on extreme years with particularly high temperatures, as those predicted by the more pessimistic ("business-as-usual") A2 scenario, and in years with low-intermediate disease pressure. This situation might occur more frequently if temperatures increase further, and decrease overall mildew severity.


Heavy infection of powdery mildew on grapes.

A2 scenario

Scenarios are possible views of how the future might unfold. Long-term emissions scenarios developed by the Intergovernmental Panel on Climate Change, have been widely used in the analysis of possible climate change and its impacts. The A2 storyline and scenario family describes a very heterogeneous world, based on increasing global population.

3. Rising temperatures, growing pests, harvesting grapes: a complex system

In conclusion, the multiple interactions between pests and plants make it necessary to consider them jointly as a system, rather than two separate elements (Grulke, 2011). This view finds support in the present simulations, which show a strong effect of host-plant development on pest pressure and suggest that current interactions between host-pest may be altered by climate change. Simulations suggested that in the warmer, more profitable viticultural areas of the study area increasing temperature might have a detrimental impact on susceptibility to European grapevine moth due to increased asynchrony between the larvae-resistant growth stages of grapevine and larvae. On the other hand, the increase in pest pressure due to the increased number of generations might not be as severe as expected on the basis of the pest-model only, due to the advance in harvest dates which would limit damages of late generations, especially for early grapevine varieties like Chardonnay. Simulations for powdery mildew showed a decrease in simulated disease severity especially in years with a later onset of the epidemics (assuming a low-intermediate disease pressure) and in the climate scenario of higher temperature increase.

To know more

Amelia Caffarra, Monica Rinaldi, Emanuele Eccel, Vittorio Rossi, Ilaria Pertot, 2012 Modelling the impact of climate change on the interaction between grapevine and its pests and pathogens: European grapevine moth and powdery mildew. *Agriculture, Ecosystems &amp. Environment* 148, 89-101.

THE ENVIROCHANGE PROJECT

The EnviroChange project focuses on global change and sustainable management of agriculture in highly developed mountain environment.
It aims at assessing the short-term biological, environmental and economic impact of climatic change on agriculture at the level of the Trentino region particularly on quality and pest management that are more likely to be influenced by climate change in the short term. The final aim is to preserve and improve the quality of life of habitants, protecting environment and biodiversity for the future generations, as well as to represent a model for sustainable development of mountain areas.

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