Adapting greenhouse climate for enhanced biocontrol and better performance of plant protection products

In greenhouse crop production, climatic parameters are often manipulated to optimize plant growth. Greenhouse climate has profound influences also on pests and their natural enemies used for biocontrol. The responses of arthropod pests, plant disease agents and natural enemies to constant temperatures and humidity are relatively well known, but many pertinent questions remain unsolved for pest and natural enemy biology and behaviour in conditions created by the newest greenhouse climate technologies and approaches. Greenhouse climate can be optimized also to benefit natural enemies and to work against pests and plant diseases, but we know less how to make this happen than we know how to manipulate plant growth through temperature, humidity, CO_2 and light conditions.

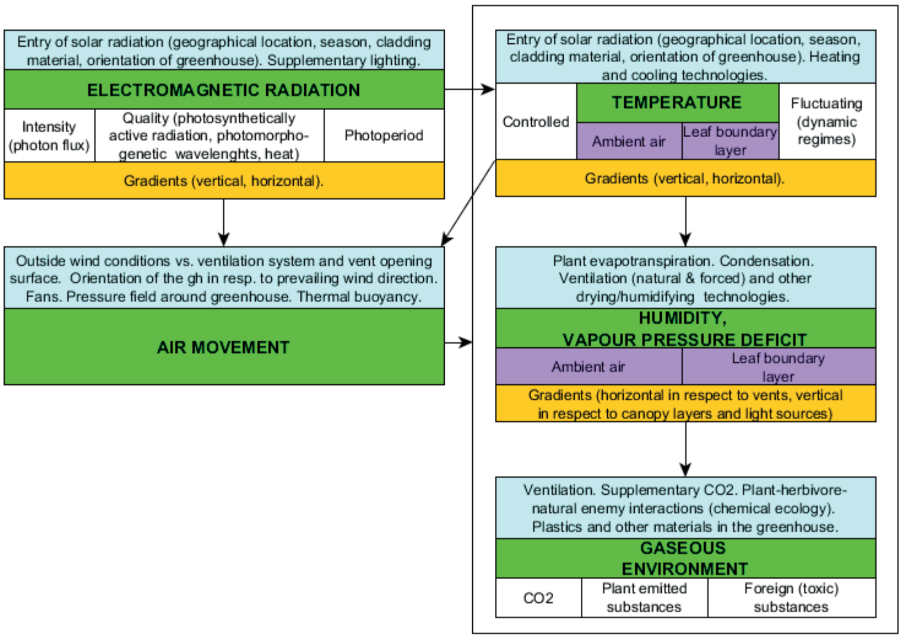

Figure 1. The key components of greenhouse climate influencing crop plants and crop-pest-natural enemy interactions. Blue cells: factors influencing the magnitude of the climatic component in the greenhouse. Air movements even out temperature, humidity and gas gradients inside the greenhouse, and are themselves influenced by solar radiation and temperature conditions through pressure differences created between the inside and the outside of the greenhouse. CO_2 is by far the most important component of the gaseous environment. Plant-emitted volatile organic compounds and occasional foreign substances such as pesticide fumes also form a subcomponent of the gaseous environment.

New technologies

Temperature and humidity control technologies are moving towards semi-closed and closed greenhouses that facilitate closely controlled temperature and humidity levels. Another line of development are dynamic temperature regimes that follow the fluctuations of the outside temperature to save energy. Both types of technologies create the possibility for continuously high CO_2 concentrations in the greenhouse, because of the reduced need of opening vents for removing excess heat and humidity. In subtropical regions, natural ventilation is still the dominant technology for removing excess heat and humidity from the greenhouse, but other options are warranted. The developments of supplementary lighting needed in northern greenhouses in autumn and winter months are currently responding to the expanding availability of narrow-bandwidth LED-lights (light-emitting diodes).

The adoption of LED-lighting will profoundly change temperature and humidity conditions in greenhouses compared to the use of the still prevailing lighting technology, the high-pressure sodium lamps.

We can do more with climate against pests

Even for temperature and humidity there is room for improvement in understanding how pests and beneficial organisms respond to these climatic variables. The distributed climate (temperature and humidity patterns inside the greenhouse) and the microclimate on the surface of leaves (where most organisms live) are nowadays better known thanks to advanced measurement technologies, analytical and numerical modelling approaches and geostatistical methods.

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Such knowledge can and should be better utilized for predicting pest and natural enemy development and behavior and for purposes of manipulating climatic conditions for the detriment of pests and the benefit of natural enemies to encourage pesticide-free production in both organic and integrated production greenhouses.

Examples on the effect of greenhouse climate on pests and their natural enemies:

- Thrips are killed in crop clean-up by raising temperature above 40 °C and keeping humidity very low for 1-3 days .
- Raising temperature by 4-5 °C for 3 h increases pesticide efficacy against thrips due to increased flight activity of the pest.
- Parasitoid *Eretmocerus eremicus* performs better than *Encarsia formosa* against whiteflies in low light levels in the winter.
- Elevated CO_2 levels and continuous lighting halve the fecundity of the greenhouse whitefly (*Trialeurodes vaporariorum*).
- UV-B wavelengths given in non-phytotoxic dosages for max. 5 min. every third night keep powdery mildew, a fungal disease of plants, in control.
- The infective units (conidia) of *Isaria fumosoroseus*, a fungus that kills insects, persist better on wet foliage and on foliage submitted to wetting–drying cycles, than on dry foliage.

Future Research

By knowing better how pests and natural enemies respond to climatic conditions two things become possible for enhanced plant protection:

- manipulation of the greenhouse climate not only for the benefit of plants, but also for natural enemies.
- improving predictions on the population development of pests and natural enemies.

With improved predictions, it becomes easier to know more exactly when to make decisions regarding extra release of natural enemies, doing chemical backup treatments, or knowing how elevated CO_2 or other factors slow down pest population development and help in controlling them. All this, however, requires that we gain more information on pest and disease biology in conditions of semi-closed or closed greenhouses, fluctuating and distributed temperature conditions and under different lighting regimes and technologies. Climate-based prediction models and warning systems that aid in plant disease management pave way for such developments also for arthropods so that coupling climate-based plant models with pest and natural enemy population models becomes part of greenhouse crop protection practice. Several research needs to reach these goals can be discerned:

1) Development of climate-based population models for pest and beneficial arthropods and plant disease agents - this requires studies of key pests' temperature, light and humidity responses.
2) Coupling climate-based plant models with those of pest and natural enemy biology and behavior to see which approach is more feasible, considering that the crop always comes first: manipulating the climate or predicting the development of pests and beneficials and acting better upon such predictions for pest management.
3) Performance of key pests and biocontrol agents in climate conditions created for the sake of energy efficiency and reduction of humidity and temperature problems: closed and semi-closed greenhouses, greenhouses with cladding materials creating diffused lighting conditions, fluctuating temperature regimes, specific light spectra for plant growth and defense, and for manipulating biology and behavior of pests and beneficial organisms.
4) Early warning and decision support systems (DSS) for prognosis and timing of control treatments for more pathogen and arthropod pest species.
5) Implementation of climate-based population models in practical greenhouse growing.
6) LED-lights can be used to control certain pathogens with specific wavelengths, but not all pathogens respond similarly. Integrating LED-based technologies in crop production regimes requires careful studies in order not to benefit some pest species while controlling others.
7) Specific wavelengths used for attracting and trapping pests and manipulating daily rhythms with specific wavelengths to disrupt arthropod life cycles.

Figure 2. LED-lightning in a greenhouse cucumber crop.

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Author: Irene Vänninen
Affiliation: Natural Resources Institute Finland (Luke)
Contact: Irene.Vanninen@luke.fi
Authors of the figures: Irene Vänninen

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