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An algorithm for optimal fertilization with pure carbon dioxide in greenhouses

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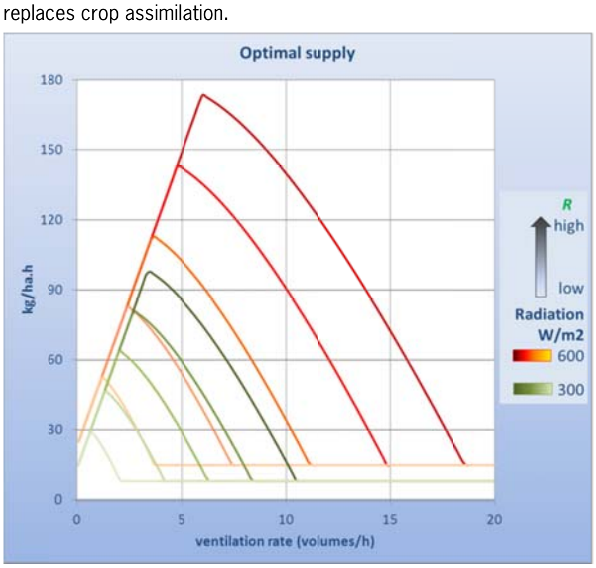
Background

Carbon fertilization–made possible by the direct application of heating fumes–is one of the factors leading to the high productivity of Dutch glasshouse horticulture. Energy saving and renewable energies ensure that there are less fumes around, a slump gradually made up by piped or bottled CO_2. Bottled CO_2 is increasingly sold at competitive prices also in the unheated greenhouses of the Mediterranean region. Allowing for a higher than external concentration under ventilation implies that some of the supply will end up outside the greenhouse, rather than in the crop. This increases the cost of getting a given amount of CO_2 into the crop, but it does not necessarily reduce profit. Therefore an economic management of CO_2 fertilisation is badly needed. We developed an optimisation algorithm and tested it in an experimental greenhouse, in the framework of the EU-financed FP7 cooperation project EUPHOROS.

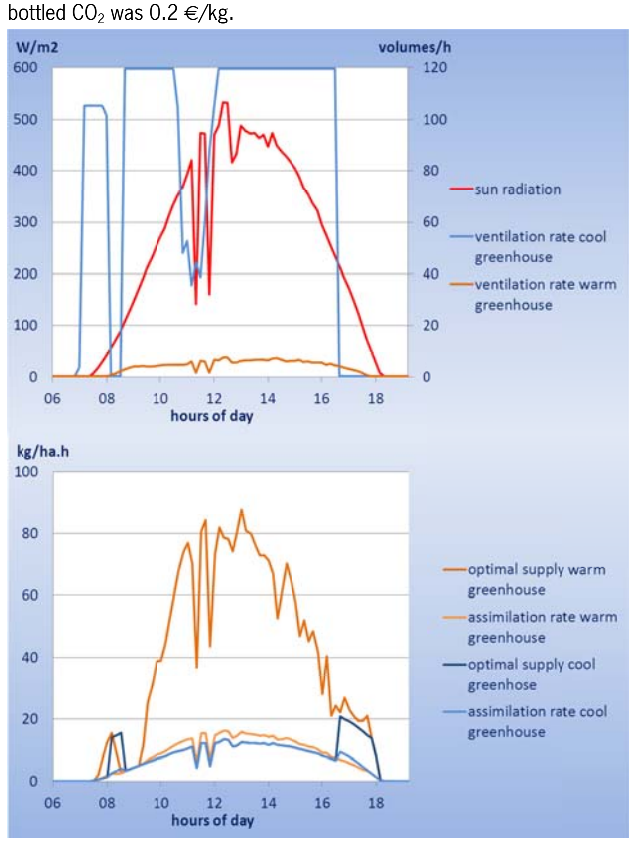
The algorithm

The supply of CO_2 must balance the assimilation and the loss through ventilation. The optimal supply maximizes profit, that is the **value** of 1 kg assimilated CO_2 (the expected value of yield times a "CO_2 fixation efficiency") minus the cost of the supply (the **price** of 1 kg CO_2). It was demonstrated that the optimal rate only depends on the ratio ***R*** between value and price of CO_2 (which the grower has to enter) and not on the two singularly. The figure below shows that–under given conditions (of radiation and ***R*** = value/price ratio)–the optimal supply rate rapidly increases with ventilation rate and then decreases to the level that replaces crop assimilation.



Results

As both assimilation and ventilation requirement vary with the conditions, the optimal supply has to be calculated on-line by the climate computer. The components of this optimisation algorithm are a simple assimilation model and a routine to determine on-line the ventilation rate through standard climate measurements. The figure below shows the results for one sunny spring day in two compartments: one very well ventilated and one allowed to become warmer. The crop was tomato, expected to be valued at 1 €/kg (value of 1 kg assimilated $CO_2 \approx 5.5$ €) and the price of bottled CO_2 was 0.2 €/kg.



Conclusion

Whenever carbon dioxide is not available simply as the rest product of heating, it must be supplied in the most economical fashion. This ensures the best possible return for the grower and prevents unnecessary emissions. The optimal CO_2 supply rate has to be determined on line, in view of the actual ventilation rate and of the potential assimilation. We have shown that a simple assimilation model and a routine to determine ventilation on-line can be combined into an optimisation algorithm, that can be implemented in a climate computer, to calculate in real time the economically optimal CO_2 concentration and the corresponding CO_2 injection rate.

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