Publishable summary

Project context

Protected cultivations are expanding in many part of the world, particularly in otherwise marginal agricultural land. Thanks to protected cultivation we are eating high-quality and healthy vegetables and enjoying beautiful ornamentals year-round, all at an affordable price. Protected cultivation is contributing to the economic development of formerly marginal agricultural land around the shores of the Mediterranean and farther. This is explained by the high productivity and high efficiency of use of most resources (particularly water). Nevertheless, there are drawbacks to such an intensive agriculture: for instance, the high spatial intensity of application of water, fertilizers and pesticides results in emissions: N-leaching can be some 2 g_{NO3} per kg tomato. Even un-heated greenhouse production has a Global Warming Potential equivalent to some 240 g_{CO2} per kg tomato (Deliverable 5). In addition, off-season production and production outside the natural habitat of a crop requires application of fossil fuels, with hugely increased CO_2 emissions as a consequence.

Project objectives

Eleven institutions from seven European countries have been cooperating in this project to decrease the need for resources in protected cultivation, while improving–or at least maintaining–the financial balance sheet of the grower. The greenhouse of the future can fulfil the need for safe use of resources (energy, water, pesticides) through modification of greenhouse design and management:

• <u>reduction of the need for resources</u>: mainly through smart greenhouse design. Coatings and additives can be used to improve the performance of greenhouse covers in terms of light transmission vs. thermal insulation; optimal utilisation of sun energy through efficient energy storage; reduction of the impact of pests and diseases through the spectral properties of the cover.

• <u>reduction of waste:</u> through better management of the production processes. Improve management of irrigation, fertilisation and substrate waste; automatic detection of greenhouse dysfunctions

• <u>increased productivity</u> through decision support for management of ventilation, heating and carbon dioxide supply; early detection of stress (biotic/abiotic) and response management;

Description of the work performed and the main results achieved

An environmental study of the current situation was used to identify the most critical elements of the production process, in various climatic and market conditions throughout Europe (Fig. 1). This was coupled to a complete financial assessment that uncovered significant potential for cost savings in operating costs (for example by reducing fertiliser requirements), so that suitable technologies could be developed to address the locally relevant bottlenecks and then be evaluated in practice. Results showed the largest potential for reduction of environmental impact coupled to financial gain for the grower to be: energy consumption (or application of renewable energy) in heated greenhouses; and better management of ventilation, greenhouse climate, fertilizers and substrates in unheated ones.

With respect to improved greenhouse climate, a prototype was developed and tested in Almeria, ES, that stores waste heat when cooling the greenhouse in the summertime and vice versa in the winter. The potential for energy storage can be increased by a smart design and management of ventilation, and several configurations of ventilators' area and position were evaluated and an innovative configuration proposed, Fig. 2. In Holland an innovative greenhouse was built, that couples extremely high insulation, to an improved management of humidity, resulting in a reduction of some 55% in energy consumption, Fig. 3. The potential of solar and wind power to replace fossil fuels was also evaluated, but the poor match in time between potential production and need for energy, ensures that the best perspective for renewables is through grid connection.

Figure 1. The scenarios to which the environmental and economic assessment was applied: clockwise from top left: Tomato production in a multi-tunnel greenhouse in Spain; Tomato production in a Venlo greenhouse in Hungary; Rose production in a Venlo glasshouse in the Netherlands; Tomato production in a Venlo glasshouse in the Netherlands.

New additives for plastic covers were developed and tested that may improve temperature management under high radiation and glass panel coatings were modified to optimise the trade-off between light absorption, diffusion and insulation. On the other hand, it was shown that, although UV transmittance of the cover may reduce pest e disease pressure, a good climate management is the main factor. We developed a decision support for monitoring and management of greenhouse conditions (temperature, relative humidity, ventilation and CO_2 supply) that improves productivity of resources and may help reducing problems with fungi, thanks to a model to identify periods of high-risk and the likely success of biological control programs. We have shown, for instance, that in Almeria the risk and speed of disease development could be better controlled in the novel, semi-closed greenhouse prototype than in the traditional greenhouses, especially in the spring and autumn (Fig. 4). In addition, an 'electronic nose' was tested and modified, that could prove useful in the early detection of pests and disease, although it is still far from practical application.

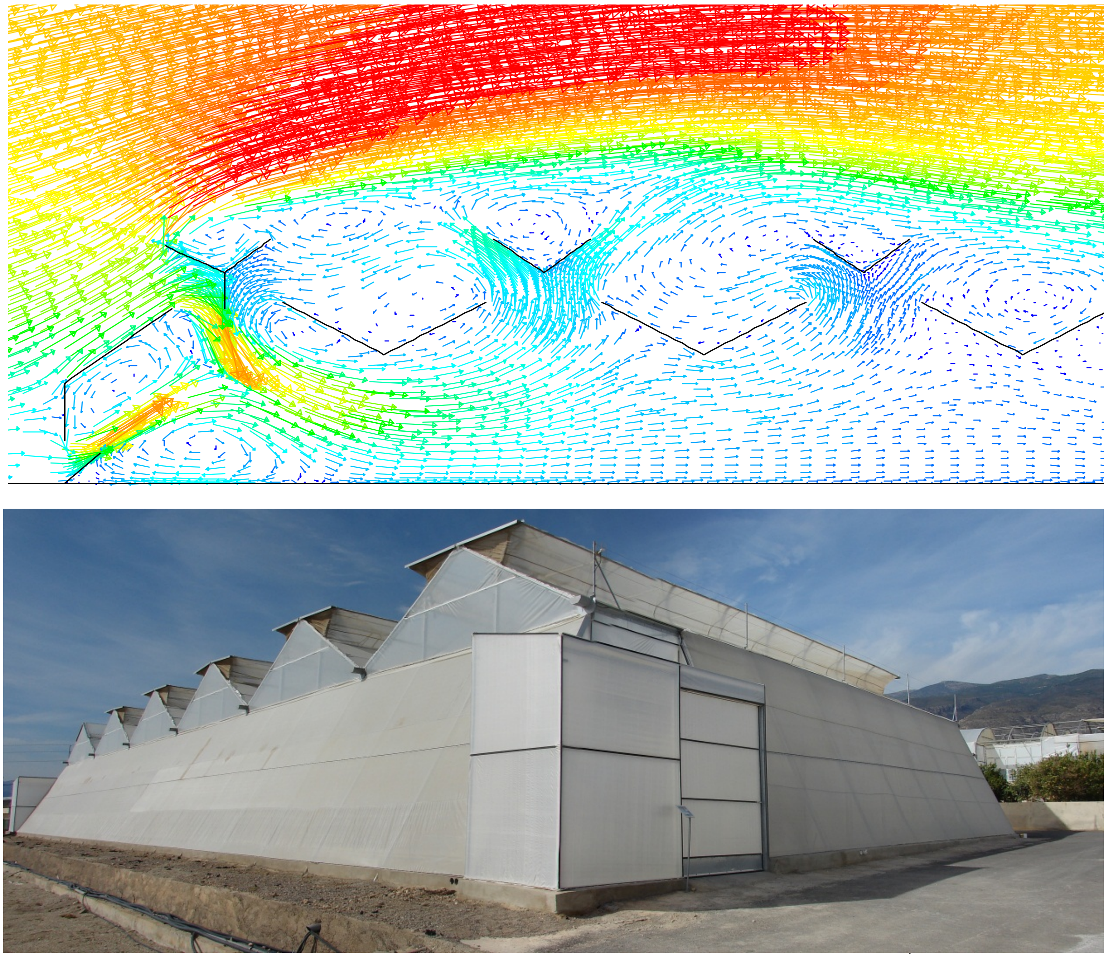

Figure 2. Top: CFD* study of the wind speed around and inside a greenhouse. Such studies were used to select the design ensuring best ventilation, and a prototype (bottom) has been built at the site of the Experimental Station of the Fundacion Cajamar, near Almeria, ES

*CFD = Computational Fluid Dynamics

Figure 3. The placing of the innovative double-glass roof on the Venlow greenhouse prototype (co-financed by the Dutch Ministry of Economy and Agriculture and the Dutch Horticultural board). Together with innovative de-humidification, an energy saving of 50% was attained, without loss of production

It was demonstrated to what extent water and fertilizers use and emissions can be curbed by recycling irrigation water (Tab. 1), though care must be taken to avoid the build-up of salts to levels that can reduce yield. In addition, with an eye to the full life cycle of the greenhouse, the reuse of spent materials such as perlite was investigated and viable options were identified.

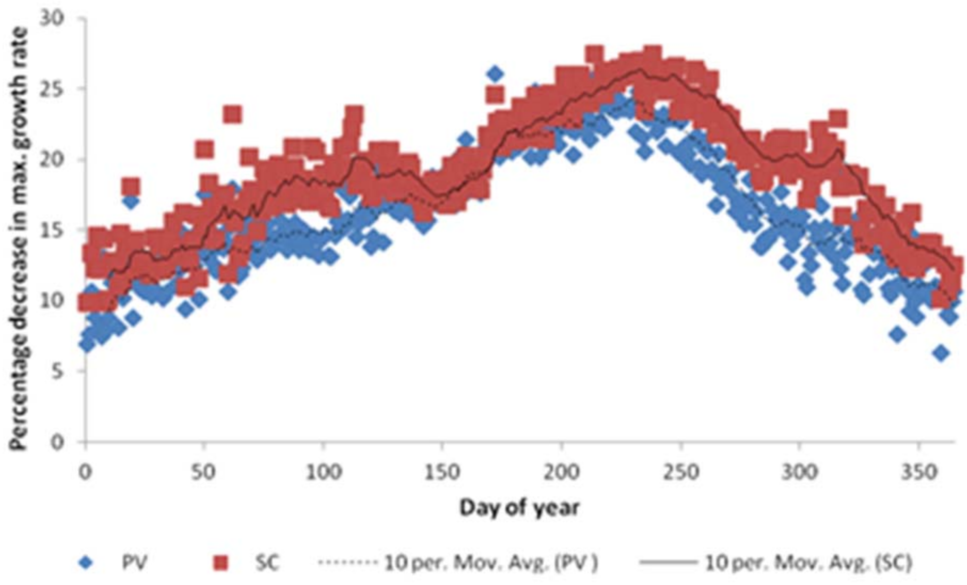

Figure 4. Modeled percentage decrease in maximum growth rate of the fungus O. neolycopersici thanks to the biological control agent B. subtilis across the year in Almeria, Spain. SC = Semi-closed (the new prototype), PV = Passively ventilated (traditional parral)

		Leaching	Supply		Saving
			Open	Closed	%
Water	$m^3\ ha^{-1}$	1067	5334	3982	25
N	$kg\ ha^{-1}$	211.7	1041	621	40
P	$kg\ ha^{-1}$	21	196	149	24
K	$kg\ ha^{-1}$	230.7	1384	1234	11

Table 1. Savings thanks to closed loop irrigation of a beef tomato crop near Pisa, IT. The columns "Supply" give the amounts applied in the open and closed-loop compartments, respectively. Saving is calculated with respect to the open loop, and leaching is the amount measured in the drain of the open loop, which thereafter was leached.

Results made available through public web-tools

The results of the project have been compiled into public available web-tools whose expected users are professionals, companies and scientists. The tools make it possible to calculate the environmental footprint of one's farm, and of possible improvements; to assess the financial consequence of modification to one's farm; to evaluate the effect of possible modifications of the opening area on the ventilation rate of the greenhouse; and provide support for the management of closed-loop fert-irrigation systems. The tools and the main project results are available from the project website www.euphoros.wur.nl that will be maintained after the life of the project and has been widely publicized in workshops, press releases and articles in trade magazines.

The greenhouse of the future will have nearly zero environmental impact. This project demonstrates that technology can help minimise the requirement for valuable resources while at the same time maximising productivity. This will help ensure that green greenhouses are a sound investment in these troubling financial times. In particular we have shown that it is possible to develop a sustainable greenhouse system that: may hugely reduce the need for fossil energy and minimize carbon footprint of equipment; has no waste of water nor emission of fertilizers and full recycling of the substrate; has minimal need of plant protective chemicals, yet has high productivity and resource use efficiency.

Partners

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