# Exchange of Knowledge between Research and Horticultural Practice through the Internet

F. Buwalda, G.J. Swinkels,
F. de Zwart, J. Kipp
and F. Kempkes
Wageningen UR Greenhouse
Horticulture P.O. Box 16
6700 AA Wageningen
The Netherlands

T. van Gastel and C. Burema
Reed Business Information
Benoordenhoutseweg 46
2596 BC The Hague
The Netherlands

H. van Bokhoven
LetsGrow.com
Westlandseweg 190
3131 HX Vlaardingen
The Netherlands

**Keywords:** growers, energy efficient production, greenhouse climate control, crop management, models

## Abstract

**Horticultural production is a complex process, the efficiency of which is rarely attributable to a single factor. In addition, optima tend to vary with internal states and outside conditions. To manage their production process, growers generally rely on rules based on experience. However, much of this experience has been acquired under conditions of relatively low fuel prices. In view of increasing fuel costs and worldwide initiatives to reduce $CO_2$ emission, horticultural producers are faced with the need to adapt their practice in order to remain economically viable. The horticultural research community can provide knowledge which may help growers to adapt to the changing conditions. In The Netherlands, internet technology is being used to facilitate efficient communication between growers and scientists. Information is collected automatically from process computers at five commercial nurseries, dynamic models are used to monitor crop and climate conditions, and nearly real-time results are published on a web portal, where it is linked with an information database and web logs by growers, advisors and researchers. The web portal (in Dutch) can be viewed at http://www.kijkindekas.nl.**

## INTRODUCTION

Modern nurseries in temperate zone countries with a long horticultural tradition, such as The Netherlands, have reached a mature level of technological development. Under such conditions, further optimization of a single production factor rarely leads to a significant breakthrough. However, further efficiency gain can be expected from exploiting dynamic properties of the crop / greenhouse production system, cost-efficient production and on-demand delivery within predetermined quality specifications. With regard to the greenhouse climate, a corresponding shift can be discerned from maintaining constant climate conditions towards using climate conditions to manage crop growth and development processes. In view of these trends, energy saving measures are unlikely to be adopted by growers unless they become an integrated part of the integral crop management practice.

With regard to energy efficiency, relevant questions include: (i) at low light levels, is it useful to maintain a high (temperature driven) rate of development? (ii) how useful is $CO_2$ enrichment, depending on light level and ventilation rate? (iii) as the amount of energy required to raise the temperature in the greenhouse by one degree varies considerably between days and even within a day, is it allowable to shift some of the heating to the more economic moments? (iv) since condensation risk is known to vary within and between days, how much heat should be supplied to reduce the risk of condensation?

In order to obtain answers to these questions, growers turn to scientists and ask them to provide new and more efficient operational rules. However, the answers to these questions can generally not be given in terms of rules, as the best decision varies with crop states, other environmental factors, cultivation targets and market conditions. The

Proc. IS on Greensys2007
Eds.:S. De Pascale et al.
Acta Hort. 801, ISHS 2008

alternative approach of teaching growers the mechanisms behind the most relevant crop processes also has serious drawbacks. Traditionally, scientific knowledge in the sciences is organized in terms of descriptions of the effects of some factor x on an object or phenomenon y. However, greenhouse production is a complex process, depending on many different physical and physiological sub-processes, influenced by internal states and external conditions. Given this complexity, growers find it difficult to apply generic knowledge to specific situations. Even if the theory is well-understood, essential information is lacking, since many of the actual rates and states, such as the greenhouse ventilation rate and heat fluxes, current source/sink balance, developmental stage, carbohydrate status, as well as rates of development, photosynthesis, respiration and growth, are unknown and also difficult to measure directly.

In view of these considerations, the present project takes the approach of using dynamic models as a generic method to organize knowledge on mechanisms and processes, and to apply it to specific situations. Supplied with nearly real-time information from the nursery, models are able to compute a broader characterization of the current situation and act as soft-sensors for many of the difficult-to-measure rates and states of the greenhouse/crop system. So, rather than informing the grower on generic principles, a model-based system is able to provide information regarding the consequences of these principles for the specific situation at the nursery under the current conditions.

Three aspects are being tested, which may improve knowledge exchange between practice and research: (i) the experience-based knowledge of growers is treated on an equal footage as the process-based knowledge of researchers; (ii) displaying real-time model output makes it possible to deal with the context-dependency of complex dynamic systems; (iii) extending the calculations into the future enables growers visiting the site to anticipate the effects of changing weather conditions and adjust the settings of their climate controllers in order to increase the energy-efficiency of their production process.

## MATERIALS AND METHODS

Five nurseries are currently acting as data sources for the project. Three of these, producing tomato, Ficus and Freesia, are located within or near the Westland glasshouse area in the western part of the country, a Chrysanthemum grower is located in the south-easterly Limburg province, and a second tomato grower is located in the Friesland province in the north. In addition to the growers, the associated cultivation advisors participate in the project.

Each nursery receives the local 7 day weather forecast, supplied by Hoogendoorn Growth Management (Vlaardingen, the Netherlands) in cooperation with MeteoConsult (Wageningen, The Netherlands), which is updated twice per day. Extensive data on greenhouse climate conditions and internal states of the climate controller is collected at a frequency of once every 5 minutes and stored in a database on the server of LetsGrow.com (Vlaardingen, the Netherlands).

Using an XML based web client, a routine in Matlab (The Mathworks, Natick, USA), running on a PC at Wageningen UR Greenhouse Horticulture (Wageningen, The Netherlands) collects the data stored on the LetsGrow.com server at a frequency of once every 15 minutes. Routine simulations are performed using the greenhouse climate model KASPRO (De Zwart, 1996). These simulations integrate recorded data from the climate controller into a comprehensive time course of heating pipe temperature, ventilator opening, air exchange rate, supplemental lighting, screen position, energy flux, CO2 concentration and air relative humidity as dependent on greenhouse states, climate controller settings and weather conditions. By using the local 7 day weather forecast as additional input, the time course is extended one week into the future.

Model output includes: a real-time energy balance of the greenhouse/crop system (Fig. 1); estimated daily fuel efficiency over the period stretching from 4 days in the past to the next 4 days in the future (Fig. 2), time course of condensation risk this present day and the next (Fig. 3), local forecasts of daily global radiation sums and average daily temperature projected against the 80% percentile over the last 10 years, ranging from 4 days in the past to 4 days into the future (Fig. 4). In addition, photosynthesis, respiration and development modules from the existing crop models INTKAM (Gijzen, 1996) and sweet pepper (Buwalda et al., 2006), running with nominal parameters, are applied to compute real time response of the photosynthetic process to variations in light, temperature and CO2 concentration (Fig. 5), and an indicative time course of the ratio between crop growth and development (Fig. 6).

The output of each model is stored in an automatically generated graph in JPEG format. Included in the graphs is a time stamp indicating the time at which the original data were collected from the climate computer at the nursery. With every iteration, each model generates an extra code to characterize the current situation (e.g. today is a clear but cold day), telling a simple database manager to fetch the appropriate explanatory HTML text to display with the graphs. Graphs and explanations are automatically uploaded onto a web server for display in the web portal http://kijkindekas.nl.

The web portal is maintained by the publishing company Reed Business Information (The Hague, The Netherlands). A dedicated journalist regularly interviews the growers and advisors regarding their recent experiences, cultivation targets, concerns etc. These interviews are published on the web portal as ‘web logs’, for visitors to read and comment on. In addition to model output and associated explanations and the web logs, the portal provides links to a database containing elementary explanations of background principles, such as the difference between sensible and latent heat, greenhouse heat loss and heating requirements, water vapour partial pressure and condensation, crop photosynthesis, transpiration, etc.

## RESULTS

Figures 1 – 6 have been adapted (translated) from original graphs (in Dutch) that the system has posted automatically on the internet. Updated graphs, containing information based on data collected at the participating nurseries, can be viewed at www.kijkindekas.nl. The graphs refer to local conditions and processes that usually have occurred less than 30 minutes earlier. System uptime is better than 98%. This demonstrates that it is technically possible to apply internet technology to supply nurseries in different areas with nearly real-time site-specific results of model calculations, performed at a central location such as a research institute. There are no substantial limitations to increasing system uptime and decreasing the time between data collection and displaying model results even further. The participating growers recognise the results displayed as realistic and useful, but seem hesitant to depart too far from their established practice on the basis of the information presented. For instance, no grower has yet adjusted temperature settings according to the information on heating efficiency displayed in Figure 3. On the other hand, calculations of condensation risk are closely watched by the participating tomato growers. From the weblogs the growers regularly contribute, it is clear that they recognise the potential for increasing the energy efficiency of their production process.

Among Dutch growers in general, the existence of the web site is known fairly well. However, many indicate that they are too busy to concentrate on information that does not directly concern their own nursery. Yet, although they only rarely participate actively in discussions, the web site receives a fair number of regular visitors. Of all model output, the most frequently visited pages (Table 1) were the heat flux graphs (Fig. 1), followed by weather characteristics (Fig. 2) and condensation (Fig. 4).

## DISCUSSION

The horticultural community in the Netherlands has traditionally been a learning community. Stemming from a cooperative tradition, information was shared openly. These days, the concept of community learning is receiving a lot of attention in view of its potential to facilitate social change and to manage complex processes (Kranendonk and Kersten, 2007). This Communities of Practice approach was recognised and described by Wenger (1998). In spite of modern competitive economic conditions, growers still share these ideas and discuss their results within study groups. Many of such groups have adopted internet technology to exchange and compare primary data. In addition, model-based decision support has long been recognized for its potential to deal with the complexity of the greenhouse/crop-cultivation system.

However, the combination of the community learning concept and model based decision support with the use of internet technology is new. The second generation of internet technology, often referred to as Web 2.0, seems to be particularly suitable to conducive to this kind of interaction. Many web-portals include interactive elements and show various forms of real-time data and user generated content. Rather than that the retrieving of information from a web site is an isolated event, the visitor can decide to return to view updated content and interact with other visitors. So, the combination of internet and models may indeed facilitate community learning, allowing growers to increase the energy-efficiency of their production process. At the same time it can serve as an effective channel for researchers to introduce mechanistic knowledge in the ongoing discussion. After the first full season the project has operated, there are several questions which need to be evaluated: (i) is the web site interesting enough for other visitors than the 5 growers and their advisors? (ii) will visitors indeed return regularly? (iii) does the concept have enough focus? (iv) would the site benefit from more crop-specific information?

## CONCLUSIONS

A new method has been developed which enables real-time exchange of knowledge between nurseries en research institutes, using dynamic models and nearly real-time data transport by means of internet technology. Initial results look promising, both technically and in terms of discussions arising between growers and researchers. The new element is the application of models to show growers, nearly real-time, the consequences of generic principles and mechanisms in local situations. A second new element is the 2-way interaction, with growers expressing their concerns and views by means of weblogs. The results of the project will be evaluated after having maintained the web-portal for one full year.

## ACKNOWLEDGEMENTS

The authors wish to express their gratitude to the Dutch Ministry of Agriculture, Food and Nature Management and to the Horticultural Product Board for financial support, and to the participating growers and advisors for openly contributing their views.

### Literature Cited

Bin Liu and Heins, R.D. 1997. Is plant quality related to the ratio of radiant energy to thermal energy? Acta Hort. 435: 171-182.

Buwalda, F., van Henten, E.J., de Gelder, A., Bontsema, J. and Hemming, J. 2006. Toward an optimal control strategy for sweet pepper cultivation - 1. A dynamic crop model. Acta Hort. 718:367-374.

De Zwart, H.F. 1996. Analyzing energy-saving options in greenhouse cultivation using a simulation model. PhD Thesis, Wageningen University, Wageningen.

Gijzen, H. 1992. Simulation of photosynthesis and dry matter production in greenhouse crops. CABO Simulation Report TT28, Wageningen.

Kranendonk, R.P. and Kersten, P.H. 2007. Midlife Communities of Practice: Experiences and Alignment American Behavioral Scientist; 50; 946.

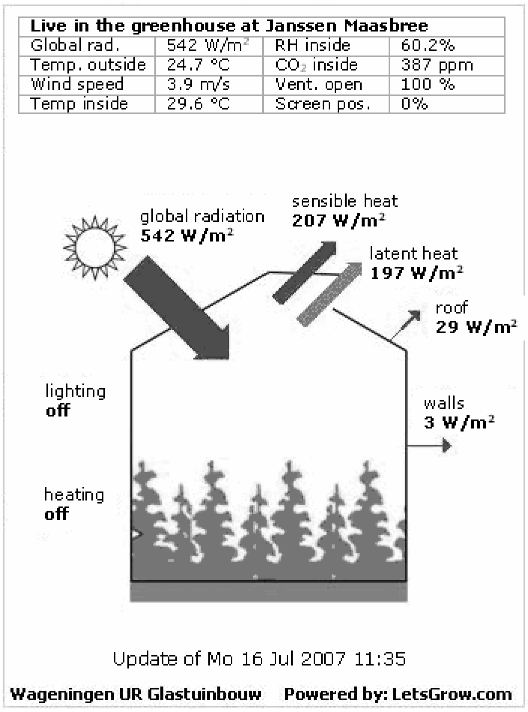
Wenger, E. 1998. Communities of practices, learning, meaning, and identity. Cambridge, UK: Cambridge University Press.

## Tables

Table 1. Internet traffic generated by the different graphs computed by the model, expressed as percentage of total page views.

| Model output: | Figure number: | Traffic (% of total page requests): |
|---|---|---|
| Heat fluxes | Fig. 1 | 34 |
| Light and temperature relative to normal range | Fig. 2 | 12 |
| Heating efficiency | Fig. 3 | 7 |
| Probability of crop condensation | Fig. 4 | 12 |
| Current photosynthetic rate | Fig. 5 | 6 |
| RRT Plant balance | Fig. 6 | 9 |
| Other | | 19 |

## Figures

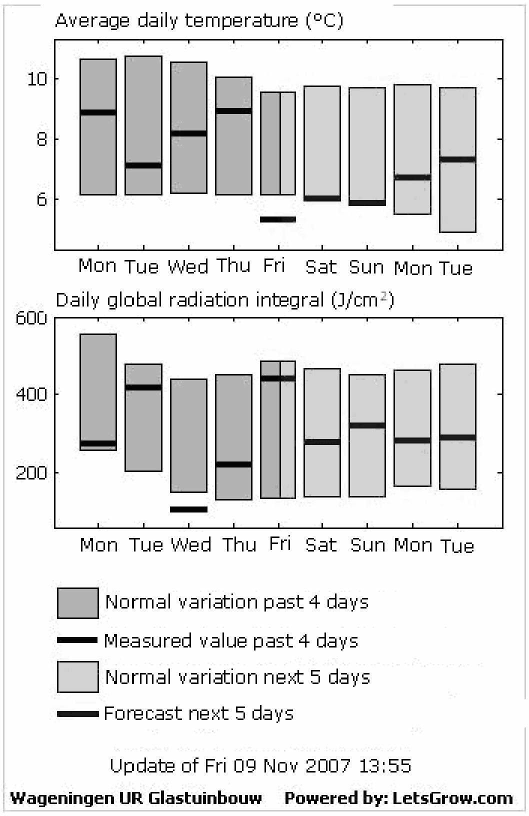


| Live in the greenhouse at Janssen Maasbree | | | |
|---|---|---|---|
| Global rad. | 542 W/m$^2$ | RH inside | 60.2% |
| Temp. outside | 24.7 °C | $CO_2$ inside | 387 ppm |
| Wind speed | 3.9 m/s | Vent. open | 100 % |
| Temp inside | 29.6 °C | Screen pos. | 0% |

Update of Mo 16 Jul 2007 11:35

Wageningen UR Glastuinbouw Powered by: LetsGrow.com

Fig. 1. Current heat flux (W m$^{-2}$) at one of the example nurseries: Janssen Maasbree, located in the Dutch province of Limburg.



Update of Fri 09 Nov 2007 13:55

Wageningen UR Glastuinbouw Powered by: LetsGrow.com

Fig. 2. Top: Recorded local average daily outside temperature (°C) over the period ranging from 4 days in the past to the predicted temperatures 4 days in the future (horizontal lines), projected against the 80% percentile range of average daily outside temperatures over the period 1996-2006 (bars). Vertical line in the middle bar indicates the present moment.

Bottom: global radiation integral outside (J cm$^{-2}$ d$^{-1}$), presented in a similar graph.

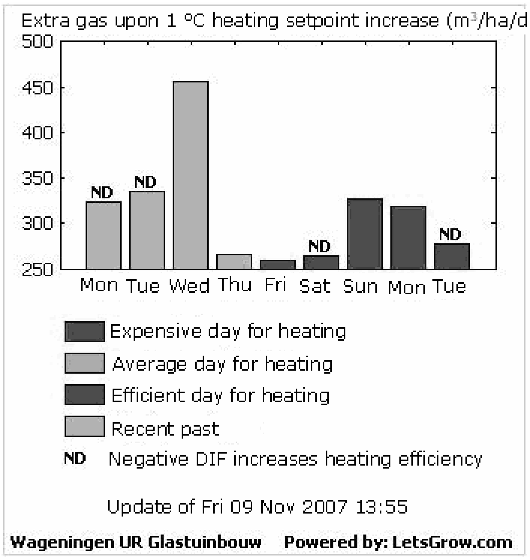


Fig. 3. Extra fuel required per day (m$^3$ natural gas ha$^{-1}$ d$^{-1}$) upon raising the heating setpoint by 1°C over the period ranging from 4 days in the past (left), including the present day (middle bar) to 4 days in the future (right). In addition, the model calculates whether a targeted ADT is most efficiently reached when day temperature is higher than night temperature or vice versa (night warmer than day = negative DIF). In the latter case, 'ND' is indicated on top of the bars.

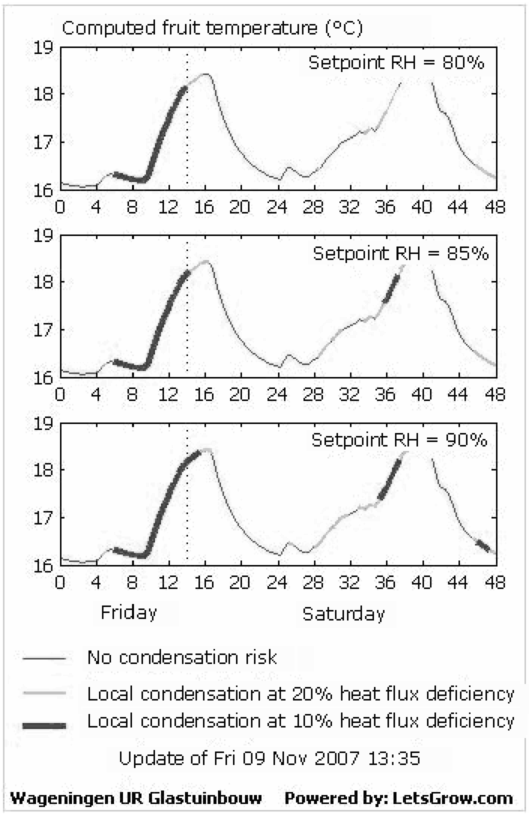
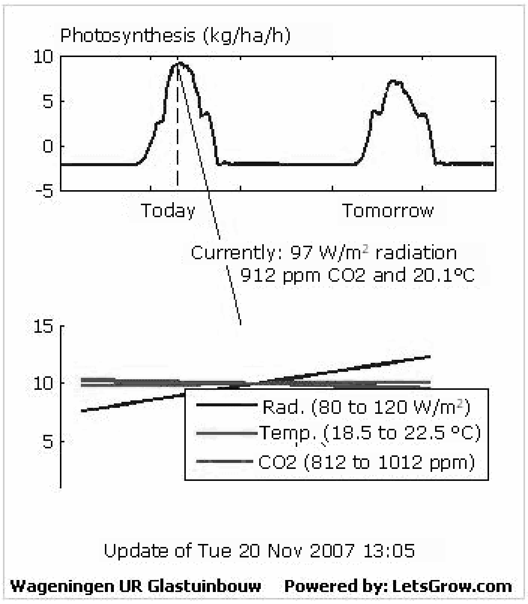


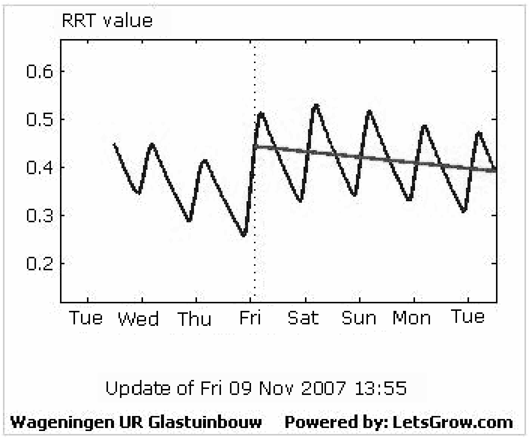
Fig. 4. Time courses of fruit temperature as calculated by means of a heat balance model, depending on the threshold setting of the relative humidity control routine of the greenhouse climate controller. The format of the temperature line is changed according to the condensation risk. A wide line indicates that already at moderately cold spots the risk is significant (local heating power deficiency of 10%); a slightly more narrow line indicates a risk at a more pronounced local heating power deficiency of 20%. The dotted, vertical line indicated the present time.



Currently: 97 W/m² radiation 912 ppm CO2 and 20.1°C

Update of Tue 20 Nov 2007 13:05

Fig. 5. Time course of the rate of net photosynthesis (kg $CH_2O$ $ha^{-1}$ $h^{-1}$) during the current day and tomorrow. The dashed, vertical line indicates the present time. Current global radiation flux ($W/m^2$), $CO_2$ concentration (ppm) and greenhouse air temperature (°C) are indicated below the time course. The bottom half of the figure shows the current response of photosynthesis to variations in radiation, temperature and $CO_2$ levels. Slopes of the response curves indicate the current sensitivity of photosynthesis tot each of these factors. Response curves range from 20% below current greenhouse value to 20% above the current value.



Update of Fri 09 Nov 2007 13:55

Fig. 6. An indication of the time course of the ratios of net photosynthesis and the rate of development. Developent is estimated by means of a simple, linear thermal time model with base temperature 10. The ratio is buffered by displaying the running average value over 2 days to mimic the effect of carbohydrate buffering in a real crop. The use of the term RRT value was inspired by the work of Bin Lu and Heins (1997).