Evaluation trials of potential input reducing developments in 3 test locations.

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EUPHOROS: Evaluation trials of potential input reducing developments in 3 test locations.

Deliverable 19.

1- Location Almeria, Spain.
2- Location Bleiswijk, The Netherlands.
3- Location Tuscany, Italy.



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Abstract UK
Within the four-years project EUPHOROS tools with a potential to reduce the use of inputs in horticulture developed by industry and universities where tested in 2010 and 2011in combinations relevant to three European test-sites. **In Almería,** with a **Tomato** crop, a greenhouse film cover (CIBA) with a NIR absorbing coating was evaluated. NIR-absorption lead to a decrease in production equal to the loss in light transmission. New developments should focus on NIR reflection instead of NIR absorption. A thermal day storage system (EEFC) allowed to heat the greenhouse at night with the heat collected during the day, potentially saving in heating costs, although economically unfeasible at the present market and energy price conditions. The evaluated smart-dust climate measurement system (Hortimax) and a CO_2 optimizing software (WUR and Hortimax) are ready to implement. **In Bleiswijk**, with a **Rose** crop, two of the tested developments are ready to be implemented in practice: a cover of Diffuse glass with a AR coating (GroGlass) that lead to a production increase of 5,2% more stems, and a Rockwool plug-slab combination that decrease the substrate volume by 20%. Further development (more speed and autonomy), is needed for the electronic nose as an early warning device for pests and diseases. A transpiration model to adjust irrigation will need further adjustments and validation in practice. The two developments tested in **Tuscany** with a **Tomato** crop (a closed-loop fertigation system and quick test for monitoring nutrients) are ready to be implemented. The results served to give feed-back to the developing partners and firms, for their subsequent development.

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Summary

The overall objective of the four-years project EUPHOROS is the development of a sustainable greenhouse system that minimizes the use of inputs and emissions to the environment, with high productivity and resource use efficiency.
During the first two year of the project, project partners from universities and industry have worked on the development or improvement of a diversity of innovative tools and systems to reduce energy, water, fertilizers, pesticides and waste. They did this within four developing working packages.
An economic and environmental analysis was conducted at the beginning of the project within a specially dedicated Working Package (WP1), to benchmark the start situation and to quantify the impact of the developments to the objectives of the project.

A sixth Working Package (WP 6) was created to integrate the tools developed in the other WP's in combinations relevant to three European particular test-sites, representing three different situations: Spain (Almería), The Netherlands (Bleiswijk) and Tuscany (Italy). Each test site has different characteristics in terms of climate, culture, cultivation technology, use of horticultural inputs, production market, knowledge development and dissemination structures, etc.
At the three chosen locations trials have been performed in 2010 and 2011, aiming the integration of tools and developments that seemed to have a potential to reduce the use of inputs in horticulture. The results served to give feed-back to the developing partners and firms, for their subsequent development. By organizing discussions with pilot growers and other stakeholders, open days and workshops growers' acceptance has been insured.

In Almería, with a **Tomato** crop, 4 developments were evaluated: A new roof greenhouse cover consisting of a plastic film (CIBA), coated with a NIR absorbing coating; a thermal day storage system (EEFC); a smart-dust climate measurement system (Hortimax) and a CO_2 optimizing software (WUR and Hortimax). The last two developments are ready to implement.
The NIR foil cover lead to a decrease in production equal to the loss in light transmission. New developments should focus on NIR reflection instead of NIR absorption. The heat storage system allowed to heat the greenhouse at night with the heat collected during the day, showing potential for considerable savings in heating costs. However, due to the installation and operational costs, such a system is economically unfeasible at the present market and energy price conditions; the developers should focus on cheaper operation costs.

In Bleiswijk, of the four developments tested with a **Rose** crop, two are ready to be implemented in practice: a glasshouse cover of Diffuse glass with a AR coating (GroGlass) that lead to a production increase of 5,2%, and a Rockwool plug-in-small slab combination that decrease the substrate volume by 20%. Two developments will require further development before they can be implemented in practice: An electronic nose as an early warning device for pests and diseases will need to improve speed and autonomy, while a transpiration model to adjust irrigation will need some further adjustments and validation in practice.

The two developments tested in **Tuscany** with a **Tomato** crop (a closed-loop fertigation system and quick test for monitoring nutrients) are ready to be implemented. However, the acceptance by the end users is low, as the pay-back time of the system is long (over eight years), and growers fear the risk for plant root diseases.

The performance of the developments tested was (and still is) amply communicated to project partners, developers, users and other stakeholders along the duration of the trials and after their finalization.

1 General introduction and report set up

This report shows the results of evaluation and integration tests performed in three European test sites with developments having with a potential to reduce the use of inputs in horticulture, according to the main overall objective of the project EUPHOROS (see 1.1).

The three tests sites are Almería (Spain), Bleiswijk (The Netherlands) and Tuscany (Italy). Each test site has different characteristics in terms of climate, culture, cultivation technology, use of horticultural inputs, production market, knowledge development and dissemination etc.

The decision of which tools to test or implement is explained in 1.3 and was based on an economic and environmental impact forecasts per location, and supported by stakeholders consultations conducted at each location in 2008 and 2009. This lead per location to a “implementation trial plan”. Although some adjustments proved necessary to the initial plans (see 1.3 and chapter 2) these led to cultivation trials in all three locations in 2010 and 2011.

The finally tested combinations as well as the obtained general results are presented as a whole per location in chapter 2.

Chapter 3 deals with the stakeholder involvement to each of the tests sites and the feed-back provided to the developers during the conduction of the trials and after, as well as the contribution of the tests sites to knowledge dissemination activities.

The detailed results of the evaluation trials involving long term crop cultivation, as it is the case of the greenhouse cover materials and the closed loop nutrient management system, are present in the following chapters 4, 5, and 6 (one chapter per location). This level of detail is not necessary for the generalist reader, but is interesting for the developers for future improvements of their products.

A final discussion of results, with a summary of results and the corresponding evaluation is shown in chapter 7 The results have provided the basis for environmental and economic evaluations, as opposed to the forecast, and have been published (January 2012) in the extensive report (Euphoros Deliverable 13 by Montero, Antón, Torrellas, Ruijs)
The performance of the developments tested was amply communicated to developers, users and other stakeholders along the duration of the trials and after their finalization. Attention to these communication and feed-back activities is given in chapter 8.

1.1 Objectives of EUPHOROS

The overall objective of the four-years project EUPHOROS is the development of a sustainable greenhouse system that minimizes the use of inputs and emissions to the environment, with high productivity and resource use efficiency.

During the first two year of the project, project partners from universities and industry have worked on the development of a diversity of innovative tools and systems to reduce energy, water, fertilisers, pesticide consumption, and waste. Existing tools for the optimization of the growing environment (innovative but robust monitoring tools for performance assessment, early detection and response management) have been tested, and improved.

The balance between environment and economy has been also addressed; for this, the environmental impact and the economic results of a reference situation (the year previous to the start of the project) were determined in order to measure the environmental and economic impact of the new tools developed. Implementation of the developed tools is another important element of EUPHOROS, as it is the circulation of the knowledge developed through the project.

The practical organization of all these elements within EUPHOROS required fragmentation of the activities in Working Packages, as it is illustrated in figure 1.1. The figure also shows the interaction between Working Packages, which increased as the project progressed. Within the working packages, several project partners have been active, which ensured interaction among partners.

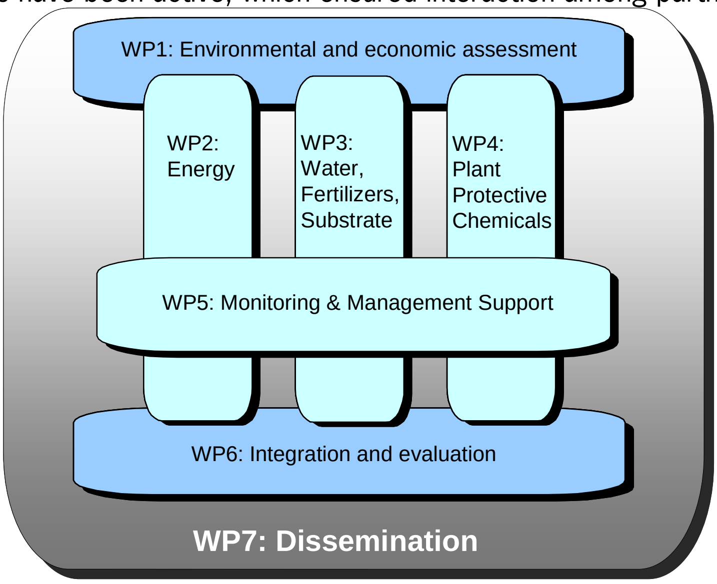

Figure 1.1. The different Working Packages within Euphoros, and their crossed interactions.

Finally, all partners and Working Packages contribute to the dissemination of the developed knowledge, for which, as illustrated in the figure, this is brought into a special working package and figuratively situated at the base of all the other activities.

1.2 Objectives of the Working Package “Integration and Evaluation”

The objective of this work package is to integrate the tools developed in the other WP’s in combinations relevant to three local markets and to test the feasibility of each combination. This is achieved through two lines of tasks or actions:

i) involvement of the end users (leading growers and/or growers’ organization, extension services) during the development phase;
ii) test and evaluation of the most promising combinations of elements at prominent applied research stations. The purpose is to give feed-back to the developing partners and firms, for their subsequent development. And, by organizing open days and discussions with pilot growers, to obtain feed-back with respect to improvements that may increase growers’ acceptance.

The first group of tasks or actions were performed in 2008 and 2009 and they have been reported in a combined report (García Victoria, N., Baeza Romero, E.J.; Balint, A., 2009, “Feed-back from growers and experts about Euphoros tools“).

The second group of tasks is reported in the present document, which forms deliverable 19 of the Deliverables list in Euphoros.

1.3 Choice of developments to evaluate per test site

The choice of available tools was huge at the beginning of the project. However, the regional characteristics and the choice of a test crop (tomato for Hungary and Spain, Roses for The Netherlands), narrowed and canalized the kind of developments that are susceptible to bring up input reductions in each particular situation. This led to a preliminary choice by each location, that was discussed in stakeholders consultations held at the three locations, where the end users could indicate their priorities and preferences.
Supported by the environmental and economic forecasts elaborated within WP 1, "Environmental and Economic Assessment", a further selection was elaborated, which was discussed in the third Euphoros Project meeting with all partners and became the trial plan for each location that is an integrant part of the above mentioned report "Feed-back from growers and experts about Euphoros tools". This final selection including the motivation is shown in Table 1.1.

Table 1: chosen combinations of developments and tools to evaluate per trial location.

Location	crop	Tool Partner / WP	Specification	Potential input reduction
Almería	tomato	Plastic coating *CIBA , WP2*	With NIR and antidirt	Assumption: if light can be increased +heat reduced => less ventilation, more [CO_2] => more production with same input.
		Disease model *Warwick HRI WP4*	powdery mildew	If pesticide use can be reduced by 10% saves 0.04 € cent/m^2 => 0.19 € investment capacity
		Thermal day storage system *WP2*	A water tank system	If 50% energy can be saved, then 0.13 €/m^2 are to be saved => 0.75 € investment capacity
		Hard sensor *Hortimax WP5*	Smart-dust grids	Assumption: if weak points in temperature control become visible, less energy is consumed to heat the whole greenhouse as problem solving concentrates on the weak points.
Bleiswijk	roses	Glass cover *GroGlass, WP 2*	AR glass with NIR-coating / *Diffuse glass with NIR coating ???*	If lamps can be switched off during 10% of the actual time (5700 h to 5130 h.) then 4,13 €/m^2 are to be saved => 23,6 € investment capacity
		Electronic nose *Warwick HRI, WP 5*	Pest and disease detection techniques	If pesticide use can be reduced by 10% saves 30 € cent/m^2 => 1,5 € investment capacity
		Soft sensor *PRI, WP 5*	transpiration model	Not quantified. Assumption: 5% water saving by reduced mismanagement; no savings in fertilizers due to "100% closed systems"
Morahalom	Tomato	Irrigation model *Unipi, WP3*	Recirculation of drainage water	If recirculation is adopted, can save between 10 and 50% on fertilizers, 0.69 to 3.45 €/m^2 can be saved => 3.4 to 17.2 €/m^2 investment capacity.
		Pest+ disease model *Warwick, WP 4*	Powdery mildew or spider mites/ both	If pesticide use can be reduced by 10% saves 0.12 € cent/m^2 => 0.6 € investment capacity
		Soft sensor *PRI, WP 5*	Fault diagnose	Assumption: 10% energy saving by reduced mismanagement, saves 0.38 € /m^2 => 2.2 € investment capacity

2 Tools and developments evaluated per location

From the end of 2009 on, each location started organizing the trials to be conducted with the partners involved.
However, during the course of the preparations it turned out that the test plans presented above could be brought to an end in the planned shape, but some plans turned out to need adjustments.

The main change concerned the replacement of the test location in Hungary by the test location in Italy. Due to the financial crash of Morákert, the growers cooperative responsible for the trials in Morahalom, Hungary, they could no longer perform the tests for Euphoros. An alternative location was proposed in Italy, where the potential savings in fertilizers by using closed loop recirculation systems was comparable to that of Hungary. A commercial tomato grower in Chiesina Uzzanese (Tuscany, Italy) replaced Morakert in Morahalom (Hungary) as final test location.

This change in location affected also the planned implementation in Hungary of the pest and disease model and the fault diagnose sensor. During the year previous to the crash, climate data and pest incidence data were supplied by Morákert to Warwick to build up the model. So did the location Bleiswijk and Almería, but this was not continued by the location in Italy.

2.1 Location Almeria

EEFC started trials with **Tomato** as crop. The tools evaluated are:

- A new roof greenhouse cover from coated plastic with the following properties: NIR blocking coating, anti-dust coating (CIBA).
- a thermal day storage system (EEFC)
- a smart-dust measurement system (Hortimax)
- a CO_2 optimizing software (WUR and Hortimax)
- data were collected and provided for validation of the pest and disease model for powdery mildew (Warwick HRI)

A brief description of each evaluation method and main results follows, as well as a reference to the document that describes the detailed results.

2.1.1 NIR Blocking + anti dust coating (CIBA) plastic roof cover.

The activities started in the spring of 2010 with simulations by means of the greenhouse climate model KASPRO (De Zwart, 1989) fed by meteorological data from Almería (EEFC meteorological data) with optical data for different NIR absorbing materials provided by CIBA. The simulations showed that the NIR absorbing materials were in principle, able to exclude a part of the incident solar energy.
In August 2011, the plastic cover of two greenhouse compartments (1200 m^2 each) at the Experimental Station of The Cajamar Foundation was replaced, in one greenhouse by a standard plastic cover (reference greenhouse), in the other greenhouse, by a plastic cover with a NIR absorbing coating. During one cropping season tomato plants were grown in both compartments while representative climate parameters as well as crop growth and productions parameters were collected, in order to evaluate the performance of the covering film.
The detailed results of this experiment are shown in chapter 5. Hereunder a summary of the main results.

2.1.1.1 Main results

- The NIR-absorption lead to a higher cover temperature in warm sunny days. This difference could reach 10°C. This overwarming of the greenhouse cover had as a consequence that less water condensated in the inside of the plastic cover. However, less condensation did not affect the Relative Humidity in the greenhouse.
- The plastic cover with NIR absorption did not affect the temperature in the greenhouse, as in both greenhouses it was very similar along the whole cycle, with daily average values of 17.5 ºC and 17.4 ºC for the NIR-absorbing film and the control film respectively. Equally, the maximum temperature values were similar for both treatments, 40.9 ºC and 40.5 ºC, for the NIR absorbing film and the control film, respectively.
- The plastic cover with NIR absorption reduced both NIR and PAR transmission in the greenhouse, both with about 15%. The reduction of the NIR transmission was desirable, but the decrease in PAR transmission was a negative, unexpected result.
- The production in the greenhouse with NIR absorption coating was 15% lower than in the reference greenhouse. This reduction is equal to the reduction in the Photosynthetically Active Radiation (PAR), and therefore, to be attributed to the loss in PAR light transmission. The moment in which the harvest started was not affected, and neither was influenced the fraction of second quality fruits.
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2.1.2 Thermal day storage tank

Calculations performed within WP2 by several partners (IRTA, WUR) and the Fundación Cajamar have shown that the heat requirement of an Almeria greenhouse amounts to 84.7 MJ/m^2. However, there is a poor correlation between the moments in which energy is available and the moments when it is needed.
The use of heat storage systems enabled this miss-match between the availability and demand for heat to be reduced. The detailed results of the examined thermal storage systems are reported in deliverable 14, belonging to Work Package 2. Hereunder, a summary of the set up and main results is given.

The evaluated system, a single energy store, was developed by Cajamar within WP2 and tested within WP6. It was designed to cool and heat a 1000 m^2 greenhouse in winter, as the calculations made within WP2 indicated that to provide both cooling and heating the single store would be more economic than using two heat stores and a heat pump. To this purpose, a silo (see figure 2.1) was mounted in situ for the storage of both cold and warm water. The silo had the following basic dimensions:

Content: 60 m^3
Diameter: 4,55 m
Height: 3,88 m

2.1.2.1 Main results

With this size of energy store a good vertical stratification of the water temperatures was demonstrated. It prooved possible to extract hot water for heating and cool water for cooling the associated 1000 m^2 greenhouse. The results are presented per season:

2.1.2.1.1 Cooling and heating a 1000 m^2 greenhouse in winter

Using a single heat store to provide both cooling and heating appears to be more economic than using two heat stores and a heat pump.

- The optimum capacity of the single energy store is 3500 MJ which is provided by 56 m^3 of water (tank 2 m high and 6.0 m diameter).
- With this size of energy store, cooling the greenhouse during the heating season reduces the duration of ventilation from 1480 to 930 hours, a reduction of 550 hours.
- The estimated increase in tomato crop value resulting from raising the CO_2 concentration to 1000 ppm when the greenhouse requires no ventilation is €300.
- The economics of CO_2 enrichment depend strongly on the air leakage of the greenhouse.
- The reduction in heating cost is estimated to be €3800, but the cost of electricity used in the collection and reuse of energy has not been included.

2.1.2.1.2 Cooling a 1000 m^2 greenhouse in summer

- The capacity of the cold energy store is 5.2 MWh (300 m^3 water) if the greenhouse has no shading and 4.6 MWh (265 m^3 water) with 30% shade.
- The capacity of the hot energy store is 6.4 MWh (365 m^3 water) with no shade and 5.2 MWh (300 m^3 water) with 30% shade.
- The heat pump output is 110 kW with no shading and 75 kW with 30% shade.
- The heat transfer rate of the cooling tower is 1100 kW with no shading and 750 kW with 30% shade.

Figure 2.1. Water silo energy store, designed by EEFC to cool and heat a 1000 m^2 greenhouse. The single store is an inexpensive option for the storage of both cold and warm water.

2.1.3 Smart dust measuring system Hortimax

Wireless temperature and humidity sensors provided by the developing partner Hortimax, were installed in order to obtain maps of Temperature and Relative Humidity in different points in the greenhouse. The use of the maps is to point out spots in the greenhouse that have consistently a different climate. Horizontal temperature variations in a greenhouse are often the cause of energy losses, energy oversupply, growth retardement, and other energy wasting factors. Climate maps allow to find out the distinctive spots and look for solutions.

The system was tested after locating 20 wireless sensors (shielded and ventilated, Fig. 2.2) in an 800 m^2 greenhouse (Figure 2.3) in the Experimental Station of the Cajamar Foundation. The sensors were located at 3.7 m height (above a tomato crop) forming a regular rectangular grid. The sensors sent their data every 5 minutes to a base located inside the greenhouse which in its turn was connected via GPRS to The Netherlands, where the temperature and humidity values (nodes of the grid, Fig 2.4) were used to create the colour maps by means of interpolation techniques. At the end, in the Synopta software, a colour map of the two scalar parameters (ambient and temperature, Fig 2.5) could be observed by the user and saved at 5 minutes intervals.


Fig 2.2. Wireless sensor shielded with a ventilated cap.


Fig. 2.3. The experimental greenhouse equipped with sensors

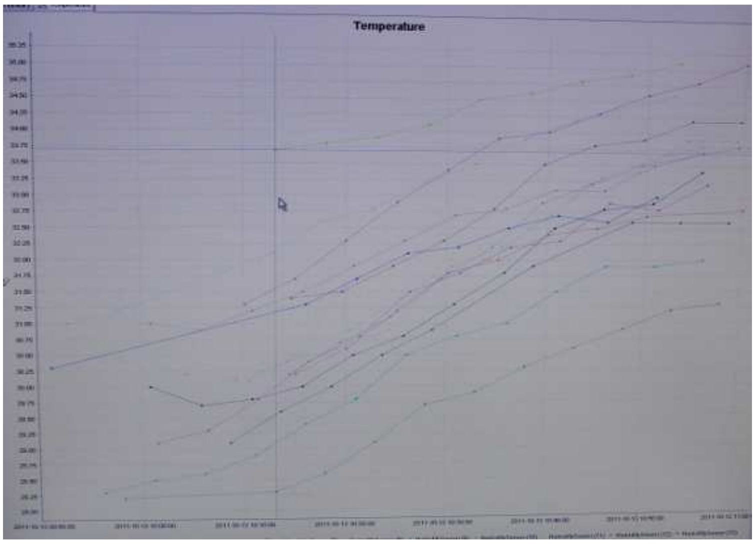

Fig 2.4. Evolution of the temperature values obtained by the set of wireless sensors.

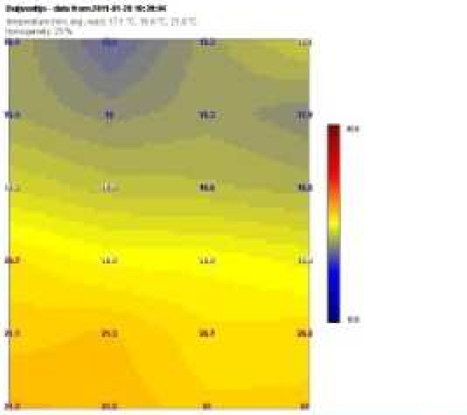

Fig. 2.5. Detail of a screen capture of the Synopta with the temperature color field.

During the time that the sensors were installed, different natural ventilation configurations were tested at noon on clear days, to obtain the temperature and humidity fields generated by each configuration, which in the next future will be used for validation of CFD simulations aimed at determining which natural ventilation configurations provide the optimum air exchange in the prototype greenhouse.

After giving feed-back to the developers, the Sensors and software are ready to implement.

2.1.4 Soft sensor CO_2 management

In Energy Work package 2, WUR developed a simple algorithm that could be used to estimate the optimum CO_2 injection rate in a greenhouse, taking into account both climate data, ventilation flow estimations and economical data (cost of CO_2, price of selling the product, etc.).

Hortimax developed a Beta version of software including this algorithm which was implemented into their most complete climate controller (Synopta, Hortimax) which was installed in the Experimental Station of the Cajamar foundation.

An implementation trial was conducted in the Experimental Station of the Cajamar Foundation although this was not integrated simultaneously with the above mentioned greenhouse trial on NIR-Blocking to avoid risks of affecting production in the NIR-trial. Instead, a separate greenhouse was used. A CO_2 enrichment protocol was formulated, establishing a maximum CO_2 concentration of 900 ppm and a minimum CO_2 concentration of 360 ppm The optimization software was fed with the data on the cost of CO_2 and the price obtained per kg of dry matter marketed, but the opening and closing of the electro valve was de-activated (the software was controlling on “shadow” mode), so the data on the optimum concentrations of CO_2 calculated by the algorithm could be obtained, although no real injection was performed in the greenhouse. The data were analysed and it was discovered that the price introduced in the software for the CO_2 was (mistakenly introduced) much higher than the actual price; thus, the optimizing system was continuously estimating that injecting CO_2 was not economic, proving, in a way, that the optimizer works well.
Follow up trials in autumn were performed where the software did not only provide as an output the optimum CO_2 concentration for each scenario, but also it made possible to obtain some intermediate data which are estimated by the program to calculate the optimum CO_2 concentration, such as the ventilation rate of the greenhouse, which are also of interest for the grower.

The software is ready to implement by Hortimax.

2.1.5 Data supply for validation of pest and disease model Warwick

During the cultivation cycle of the tomatoes in the greenhouse experiment dedicated to test the NIR-absorbing greenhouse plastic cover, climate and disease incidence data were sent to Warwick for the elaboration of a pest (*Tetranynchus urticae*, red spider mite) and disease (Oidium neolycopersium, powdery mildew) epidemiological model. The results were use to elaborate the model, which is an integral part of the Phd. thesis written by Dr. Sacha White.

Due to time constraints, the results could not be validated in practice at the Experimental Station of the Cajamar Foundation.

To proceed to implementation, the results of the model must be experimentally validated in different conditions and incorporated to a software or a user friendly Decision Support System for growers.

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To proceed to implementation, the results of the model must be experimentally validated in different conditions and incorporated to a software or a user friendly Decision Support System for growers.

2.2 Location Bleiswijk

Wageningen UR Greenhouse Horticulture performed evaluation trials with **Roses** as crop. The Tools evaluated are:

- A novel greenhouse glass cover with the following properties: diffusing glass with Anti-Reflection coating of both glass sides (GroGlass)
- Synchronized cuttings on Single Production Units (Grodan, not a Euphoros partner)
- Electronic nose and other methods for early pest and disease detection (Warwick HRI)
- Data collected to validate the soft sensor transpiration model (Wageningen UR)
- Data were collected and provided for elaboration of the pest and disease model for powdery mildew (Warwick HRI)

A brief description of the evaluation method per tool and main results follows.

2.2.1 Diffuse glass with AR coating Greenhouse cover

The activities in Bleiswijk started in January 2010 with additional fundraising for a reference greenhouse. In April 2010 the propagation and growing of the plants started by means of the propagation-cultivation system (SPU). This method is not a development within the Euphoros project but it has the potential to reduce the necessary Rockwool volume per plant by 30% with respect to normal cultivation, and that is why it was decided to implement it in the tests.

In August one greenhouse compartment was reglazed with a glass supplied by GroGlass. Another greenhouse compartment was used as reference. A third greenhouse compartment was financed by another Glass supplier; the glass supplied was also diffuse glass with Anti Reflection coating on the outer side of the glass only.

The greenhouses have a size of 144m^2. The crop, roses of the variety “Red Naomi”, a highly appreciated variety on the local market, has been cultivated from august 2010 till September 2011 (one productive year) according to normal commercial practice. Climatic and production data were collected according to the previously elaborated management and evaluation plan. Additional measurements, that must help to understand the effects of diffuse glass on plants, such as photosynthesis, light interception by the crop, light transmission by the greenhouse cover, and effects on vase life were conducted.

2.2.1.1 Main results

The detailed results of this experiment are shown in chapter 6. Hereunder a summary of the main results is presented.

- The light in the compartments with the diffuse- AR cover was less erratic than in the compartment with normal glass. As a consequence of this, there were less extreme values measured inside the greenhouse.
- The Diffuse-AR coated glass cover did not affect the temperature in the greenhouse, as the average temperature in both compartments was not different along the year.
- The flower buds in the greenhouse with Diffuse-AR coated glass cover showed a smaller difference with the air temperature than those in the greenhouse with normal float glass. When buds heat up due to high radiation, blue edges appear in the petals that reduce the market value of the flowers.
- The Diffuse-AR coated glass allowed for a higher threshold for screening; to prevent petal blueing, screening is necessary at 600 W/m^2 outside radiation. In the diffuse glass compartments, screening was necessary above 700 W/m^2 outside radiation.
- The higher screening threshold resulted in extra PAR light in the greenhouse. 2,7% more light due to less screening hours.
- The extra light resulted in a 6,1% higher production in harvested fresh weight and 5.2% higher production in number of stems in the glasshouse with Diffuse-AR coating than in the reference greenhouse with normal light.

2.2.2 Rockwool plugs on Single Production Units

The rose plants were propagated by cuttings using the Synchronization Method (Van Telgen et al., 2003) of Wageningen UR Glasshouse Horticulture in Rockwool plugs (Grodan) and once rooted they were planted in May 28th in SPU (Single Production Units) Rockwool blocks (Grodan) of 24x20x7,5 cm with 2 plants per block.

2.2.2.1 Main results

The use of the SPU with plug combination saves 20-30% Rockwool as compared to the normal method with a block on a Rockwool slab.
The SPU also allowed transport of the nearly productive plants to the trial compartments after reglazing.

2.2.3 Electronic nose and early pest and disease detection methods

Two series of measurements were performed by researchers of Warwick HRI in order to evaluate the potential of the electronic nose in commercial greenhouses (figure 2.6). The first measurements series was performed by students in March 2010 in commercial greenhouses (2 growers) and in experimental greenhouses in the Bleiswijk facilities of Wageningen UR Greenhouse horticulture in The Netherlands.
The second series was entirely performed in the reference greenhouse of the Diffuse Glass evaluation trial in the Bleiswijk complex of Wageningen UR in August 2011. During this evaluation week, not only the electronic nose, but also other methods for early detection of pests were evaluated.
Detailed results of these experiments are reported in deliverable 18, belonging to Work Package 5 (Iliescu et al., 2011)

2.2.3.1 Method first evaluation week

In March 2010 it was sampled during one week in commercial rose greenhouses with the electronic nose. Simultaneously, samples were taken to be analyzed with the more sensitive Gas Chromatography- Mass Spectrometry equipment to determine the accuracy level achieved with the Electronic nose.

The sampling took place in severely infected plants in trial greenhouses and in two commercial greenhouses, where smell disturbing agents such as sulphure, combustion gasses (for heating) and CO_2 supply were present. The pests and diseases targeting for were mealy bugs, echinothrips and powdery mildew. The data processing took place in Warwick.

Figure 2.6. E-nose measurements in commercial rose greenhouse

2.2.3.2 Main results first evaluation week

- The used equipment had insufficient discrimination capacity to distinguish healthy from diseased plants in the complex environment with contaminants at much higher concentration than the plant/disease volatiles.
- Some disturbing agents in the greenhouse need to be filtered out of the signal, or pre-concentrated prior to the measurements.

2.2.3.3 Method second evaluation week

Measurements were done to establish a baseline for clean plants and plants affected by powdery mildew, over 3 days. The powdery mildew plants had visible white spots.

The sampling was done with:

1- Cyranose 320 Enose, (Figure 2.6) linked to a PC for continuous data streaming (keeping open the post-processing option). The data has been uploaded to a computer for off-line processing.
2- FAIMS, (Figure 2.7). Experiments were performed in the same conditions as for E-nose, over 2 days. Additionally, background samples of ambient air and scent from cut flowers were obtained. The data has been uploaded to a computer for off-line processing..

Figure 2.7. FAIMS measurements in the test greenhouse (right) and outside it (left) for scent background of harvested flowers.

Next to this smell based-techniques, a visual technique was used. A small, pocket size magnifying glass is a normal tool for scouting, making possible to distinguish living small mites and insects from dead ones (as consequence of pesticide applications), or to distinguish mites from their predators. For further identification, samples are taken to bring to the lab for further identification by means of a stereo microscope. Instead, it was experimented with:

3- A handheld digital microscope. A small, handheld, portable digital microscope, Veho Discovery Vms- 001, magnification 20-200x, (figure 2.8) with its own light source (LED), allowing varying magnification was used with detached leaves and inside the greenhouse. The microscope, with the size of small light spot, is connected to a laptop through a USB-port. The images are visualized in the screen of the computer. Some images are shown in figure 2.9. Currently, images can only be viewed directly, or uploaded and retrieved, but are not processed further. The microscope was given to one of the scouts of the greenhouse complex facilities in Wageningen UR Greenhouse Horticulture to experiment during the scouting of both commercial and experimental greenhouses.

Figure 2.8. A hand-held digital microscope.

2.2.3.4 Main results second evaluation week

The main results presented per detection system used:

2.2.3.4.1 The detection of powdery mildew with the electronic nose:

- Requires approximately 5 minutes per sample
- A training set of between 4 and 10 samples per category (in this case cat1 – clean and cat2- powdery mildew infection) is needed ;
- If the web interface is used, the training set needs to be uploaded onto the server;
- Battery life is limited to 1 hour for continuous sampling; the alternative is access to continuous power line.
- The off-line classifier could distinguish between clean and infected plants with an overall accuracy of 92% on the samples tested. However, the software classified as clean 1 infected sample (false negative) and as infected 6 clean samples (false positives).

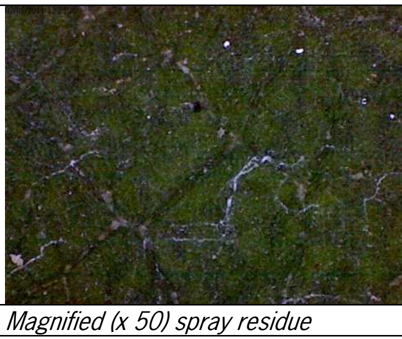
2.2.3.4.2 The detection with the FAIMS:

- Approximately 5 minutes per sample is required
- A power line is required permanently
- An additional pump with variable speed is required for sampling
- The weight and the size of the FAIMS devices makes the access difficult

2.2.3.4.3 The detection with hand held microscope

The observations below give an impression fruit of the use of the device by the professional scouts working in Wageningen UR Glasshouse horticulture that were asked to experiment with it.

- The hand-held microscope is a good alternative for the use of a magnifying binocular or stereomicroscope, as a tool to identify samples (i.e. leaves) with pests or diseases that are less common, or in situ for pests present in places that are not sampleable (like the lower, lignified parts of the stem).
- Useful as a diagnostic tool, comparable to a binocular, but cheaper, mobile, and providing directly images and films on the laptop screen.
- However, it is not a help in scouting: the rose crop canopy is too tight and provides too many possibilities for the pest to hide. The camera should be able to reach places that are unreachable to human's eyes.
- The laptop to which it needs to be connected to visualize the images impedes access to the crop (to attach it to a smart-phone might facilitate it).
- The small microscope could be of use as a scouting tool in mobile rose cultivation systems, where plants are all being transported to a central harvesting point. In this central space passed by all plants, a set of microscopes installed at different crop heights could inspect every plant. An image storage system would be needed able to link the images to a position in the greenhouse. Images could be viewed later by a grower or scout and allow for comfortable and quick screening of pests / diseases from the computer screen at a separate room, as it is nowadays happening with climate data. A software able to recognize pests could detect suspect images to offer to the scout.

		
Rose leaf with spray residue	*Magnified (x 50) spray residue*	*Magnified (x 200) spray residue*

Rose leaf with powdery mildew spot	Magnified (x 50) powdery mildew	Magnified (x 200) powdery mildew

Figure 2.9. Images taken with the hand-held digital microscope.

2.2.4 Stanghellini transpiration model

Weighting gutters were placed in November 2010 in two rose growing compartments: the compartment with the reference greenhouse glass cover and the compartment with the Diffuse – AR coated glass cover. The weighting gutters monitor the weight changes of 2 m gutters with 10 Rockwool blocks each= 20 plants per gutter that occupied 1,50 m width in the greenhouse. The total surface of the 40 plants on the gutters was 3 m^2. The weight was determined by means of “load cells” and stored at a 30 second interval. The drainage water of the 40 plants was weighted separately by means of another load cell and registered in the same way.

The data collected were compared to a modified version of the Stanghellini model for tomato (Driever, 2011, Euphoros deliverable 18).
The fit was good on a day basis, but on the long term it overestimated or underestimated transpiration, due to the marked flush effect of the rose crop.

2.2.4.1 Main results

- Cumulative transpiration was similar in both greenhouses (see figure 2.10).
- On a weekly base there were important differences between greenhouses, mainly caused by differences in LAI.
- The differential screening regime in both greenhouses (see further in chapter 5) is another important source of variation
- Total transpiration per harvested produce was lower in the greenhouse with diffuse glass (as production was higher).

However, when this empirical data were used to validate the improved Stanghellini model, it was found that:

- It is necessary an accurate determination of the light extinction coefficient, in order to calibrate the model subsequently.
- It would be necessary to obtain good values of stomatal conductance at the crop level; values used were determined by means of leaf gas exchange measurements (maximum reached at 1500 micromole m^{-2} s^{-1}) that are not reliable because model was developed for "whole plant" and gas exchange measurements were carried out at leaf level
- It would be necessary to determine the LAI of the crop at the different stages of the flush.

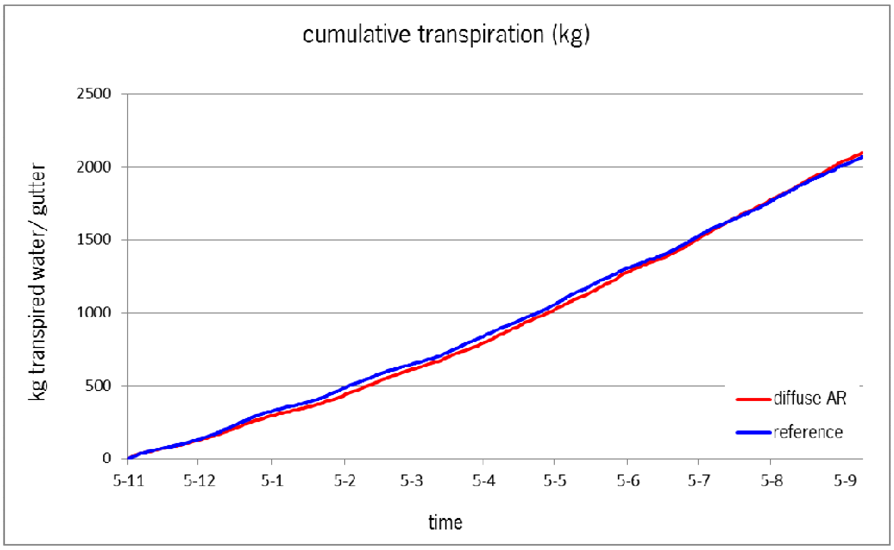


Figure 2.10. cumulative transpiration of the rose crop in both greenhouses

2.2.5 Data supply for validation of pest and disease model Warwick

Previous to the start of the main rose experiment in the greenhouses with normal and diffuse glass, a set of complete climate data collected during 1,5 year at 10 growers of one rose variety were supplied to Warwick HRI for the development of a disease model.

As in roses the pest to which Warwick focussed on (*Tetranynchus urticae*, red spider mite) is not a serious problem anymore since the use of integrated pest management, it was decided that the model would focus for roses on a disease, powdery mildew, for which the chosen rose variety was extremely sensitive.

During the cultivation cycle of the roses in the greenhouse experiment dedicated to test the greenhouse glass cover properties, empirical climate data and disease incidence data were specially recorded to provide information for the elaboration of the epidemiological model (figure 2.11) . The log book pesticide treatments was also provided, to allow a correction for non-climate related variations in the infection level.

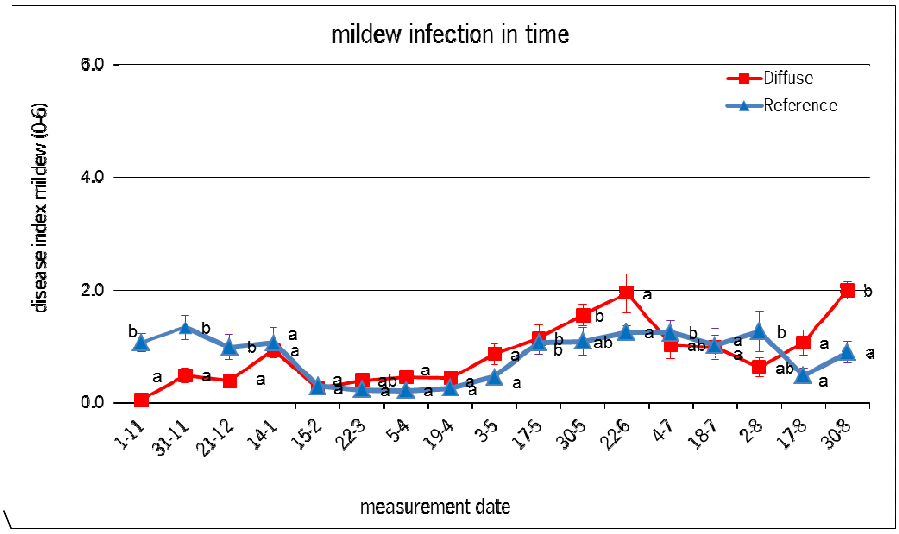


Figure 2.11. Mildew infection in time during the course of the experiment in two greenhouses: one covered with normal glass, the other with diffuse-AR glass.

The results were use to elaborate the model, which is an integral part of the Phd. thesis written by Dr. Sacha White.

Due to time constraints, the results could not be validated in practice at the installations of Wageningen UR Greenhouse Horticulture in Bleiswijk.

To proceed to implementation, the results of the model must be experimentally validated in different conditions and incorporated to a software or a user friendly Decision Support System for growers. Such a model can be used as an early warning tool to give growers information about when to expect an outbreak of the disease in order to avoid the conditions that propiciate this outbreak.

2.3 Location Tuscany

UNIPI has conducted two consecutive tests with **tomato** as crop in a commercial greenhouse in Tuscany. The first test was performed from 15th April to 21th July 2010, while the second cycle from 4th August to 13th December 2010.The tools evaluated were:

- a closed-loop fertigation system in Rockwool culture, compared to an open system (the most popular soilless system used in Italy);
- a quick –test for periodical nutrient solution analysis for nitrogen, ammonium and phosphates (Reflectoquant®, Merck KGaA, Darmstadt, Germany).;

2.3.1 Closed loop fertigation system

For the test, two small areas (60 m^2) of a commercial greenhouse with approximately 200 stems were used to compare an open fertirrigation system (the normal method used by the grower) with free drainage, and a closed system built by researchers from UNIPI. In both growing system, data about water quality, water and nutrient use, water and nutrient waste and production were collected according to the management plan.

2.3.1.1 Main results

Compared to the free drainage or open system used by the grower, the closed loop nutrient system:

- reduced significantly the use of water (21%) and nutrients (17 to 35%);
- totally avoided nutrient leaching;
- did not affect the EC and Na concentration of the nutrient solution;
- did not affect crop evapotranspiration;
- did not affect crop production nor crop quality,
- the economical analysis revealed that, if the free-drainage system is well managed with a minimum Leaching Fraction (the LF threshold for the economical convenience is 26.7%, against the grower LF of 21%), the adoption of a closed–loop system is not convenient. Although the financial results of the closed recirculating system are negative, in the open system no costs have been taken into account to 'clean' the environment by the pollution derived from the fertilisers run-off;
- the grower had evaluated positively the experience since he have understood the importance of a fine monitoring of the drainage percentage especially in the open system, in order to save the water and fertilisers.

The results of both tests are described in detail in Chapter 6 of this report.

2.3.2 Quick test for nutrient analysis

Analysing the quality of the recirculating water is an elementary Good Horticultural Practice in fertigation management, and a inevitable requirement in the case of closed loop fertigation. However, the methods used for nutrient analysis as applied in The Netherlands who have set the standards, are not followed everywhere. As a result, growers elsewhere in Europe (and outside Europe) often need to send samples to be analysed in The Netherlands. This is an expensive and time consuming operation. Although this analysis can not be totally replaced by quick tests, a quick test can be a very good decision management tool for growers between “official” analysis, reducing the number of samples that need to be sent abroad. We have calculated that growers would then send 2 instead of 10 samples a year to an official lab per hectare.

2.3.2.1 Main results

Compared to the more extensive analysis, the test show good accuracy for the ions nitrate, phosphate and chloride.
The quick test are not suitable for ammonium, boron and potassium. The main advantage of the quick tests is that, for the ions to wich it shows good accuracy, it provides good results in an immediate way.

2.4 Summary results all locations

Table 2 summarizes the results of the tools and developments evaluated in all three locations, indicating the main results, the perspective for immediate application and, when calculated in WP1, the economic and environmental impact. If these are not calculated but have a high saving potential, they are indicated with one or more +.

Table 2 Results of the tools and developments evaluated in all three locations

Location	**crop**	**Tool Partner / WP**	**Test results**	**Economic results**	**Environmental results**	**Further development**
Almería Spain	tomato	Plastic with NIR absorbing coating *CIBA , WP2*	15 % less production	No potential	No potential	NIR reflection additives instead of NIR absorption?
		Disease model powdery mildew *Warwick HRI WP4*	Contribution to model build up and validation	Not calculated system not ready for practice yet	Not calculated system not ready for practice yet	test the model in practice
		Thermal day storage system *WP2*	€3800estimated reduction heating cost ; 550 h less ventil. =more CO_2, €300 more tomatoes	Enomically unfeasible in actual Almeria situation	++	Focus on cheaper system or changing conditions
		Hard-sensor Smart-dust grids *Hortimax WP5*	Nice maps showing temperature gradient	+	+	**Product ready to implement**
		Soft sensor CO_2 optimizer *WUR WP2 and Hortimax WP5*	Contribution to software validation	+	++	**Product ready to implement**
Bleiswijk The Netherlands	roses	Diffuse glass with AR coating *Groglass, WP 2*	*5 -6% more production*	Pay-back 4 years from 1,5% prod. increase	4.6% reduction to all considered impact categories	**Product ready to implement**
		SPU rockwool	20% rockwool save	0,10-0,16 €/m^2	20.6% CED Red. in aux.eq,	**Product ready to implement**
		Electronic nose Pest and disease detection techniques *Warwick HRI, WP 5*	92 % accuracy	Not calculated system not ready for practice yet	Not calculated system not ready for practice yet	Quicker sampling User interface Accuracy increase Build in more pests
		Disease model powdery mildew *Warwick HRI WP4*	Contribution to model build up and validation	Not calculated system not ready for practice yet	Not calculated system not ready for practice yet	Test the model as an early warning system
		Soft sensor transpiration model *PRI, WP 5*	Contribution to model build up and validation	Not calculated (not ready)	Not calculated (not ready)	Improve model fit and develop implementation software
Tuscany Italy	Tomato	Irrigation model *Unipi, WP3* Recirculation of drainage water	25% less water 11 to 40% less nutrients Same production	+ / - depending on disinfection	++	**System ready to implement**
		Quick test for ion concentration determination	Accurate nitrate, phosphate, chloride; not suitable for ammonium, boron, potassium	The main advantage is to obtain immediately the result	Not applicable (helping tool to achieve closed loop)	**System ready to implement**

3 Stakeholder involvement and feed back

Stakeholder involvement was different at each location, and therefore it is treated separately.

3.1 Location Almería

The stakeholders involved in the Euphoros tests in this location are Growers, technicians (extension workers), and research centres.

3.1.1 Stakeholder involvement

In the first place, a consultation workshop was held in May 2009 to find out which of the Euphoros developments had higher chances for the Horticulture in the region (see Deliverable 4). This consultation lead to the choices explained in chapter 2.

The evaluation tests with the NIR-absorbing plastics awakened great expectations among the growers, technicians and specialists in general, and therefore, during the course of the experiment the number of visitors to the centre triplified the normal number of visitors to the centre (figure 3.1). In warm areas, heat excess is a serious problem what explains the interest of potential users of a plastic with the potential to decrease heat in the greenhouse.

Also the evaluation trials of the day-heat storage and the CO_2 optimizer counted on a lot of enthusiasm by the end users. Less enthusiastic were growers about the use of the smart-dust temperature maps. This could be due to the local situation, as not so many growers use heat or can influence climate much in the area.

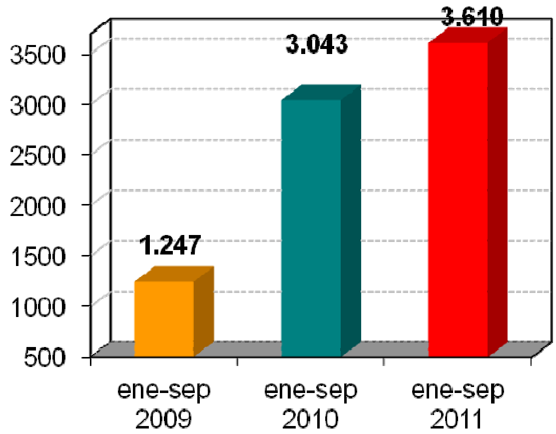


Figure 3.1. Number of visitors to the EEFC during the growing seasons in 2009, 2010 and 2011.

In June 2011, the preliminary results of the NIR-absorbing foil were presented in a workshop to which 150 persons attended; the visit to the greenhouse (Figure 3.2) was part of the workshop.
The program for this workshop is added as appendix 1 to this report.
Thereafter, in February 2012, an international course was organized in Almeria to which 25 selected students attended (see the course announcement added to this report as appendix 2) were the experiences with the developments tested in all three locations were presented.

In the same week, also a seminar with more than 200 attendants was organized in Almeria (see the seminar announcement added to this report as appendix 3) where the developments applicable to tomato (location Almería and location Italy) were presented.

3.1.2 Feed-back to developers

Feed back was supplied to the developers that allowed changes in the software (Hortimax) and made it ready for implementation.

The day heat storage was successful; feed-back to the developers (EEFC itself) includes in this case an economic evaluation, that proves the system economically unfeasible in the nowadays existing circumstances, but evaluation of the system in changing circumstances and in other temperate regions is strongly recommended.

Figure 3.2. Visitors to the trial greenhouse covered with the NIR-absorbing foil.

Feed-back to CIBA was supplied during the course of the implementation experiment. Although the simulations showed that the NIR absorbing materials were in principle, able to exclude a part of the incident solar energy, their effect in practice seemed limited, because part of the absorbed energy was transmitted to the interior of the greenhouse by convection, and in principle, reflection instead of absorption seems a more favourable option. A good NIR filtering material must exclude a high level of NIR, because the leaves of the crop are by themselves a good reflector of NIR (45%). The material must also affect as little as possible the transmission within the PAR range. Therefore, from the set of materials simulated, the best prototype was chosen (maximum NIR absorption with least possible PAR reduction) and manufactured to be tested at the EEFC facilities.
In view of the obtained results, the development of NIR blocking materials should be focussed on reflecting the NIR radiation, rather than absorbing it (as in the tests), and it should be considered that very marked effects are not to be expected due to the above mentioned good reflection properties by the crop . During the winter, the decrease in NIR transmission could be a drawback in Mediterranean climate, since the greenhouse effect is required to improve night time temperatures.

3.2 Location Bleiswijk

In Deliverable 4, the knowledge circulation structures in the Dutch greenhouse horticultural sector are explained. Stakeholder management around the work package tried to make the best use of the existing structures. So two stakeholder groups have been gathered around the evaluation tests. The group meetings took place separately, and with different frequency.

3.2.1 Stakeholder involvement

An existing IPM-rose group whose main activities are directed to the development of new strategies for

pest control was an adequate board to discuss the requirements of early detection systems for pest and diseases.
The group consist of the following members:
- An IPM rose study group organized within LTO groeiservice, including growers and advisors
- Representatives of the Pesticide industry
- Researchers from Wageningen UR
- Researchers from Warwick HRI (when available)

There were four meetings organized during the developing year; two with growers (one previous to the first experiments, one following them), and two with researchers.

A second group was specially created to be involved in the evaluation tests of the diffuse glass cover..
The diffuse glass rose trial stakeholders group meets from august on (the start of the experiment) once every four to 6 weeks. The meetings were well attended by all members involved, which are the following:
- A representative of the Dutch Ministry of Agriculture, Nature and Food Quality (co-financing organism, from half 2011 named Ministry of Economics, Agriculture and Innovation)
- A representative of the Dutch Horticultural Board (co-financing organism)
- Several rose growers
- A rose- advisor (from DLV plant)
- LTO groeiservice
- Researchers from Wageningen UR
- Researchers from the company Plant dynamics
- Incidentally, industry representatives (glass suppliers, Rockwool supplier)

Previous to each meeting, the growers visited the crop and gave cultivation management advice when needed. This ensures that the crop is grown acoording to commercial practice.

The group was very positive about the evaluated developments. The diffuse glass trial had a more than average interest from specialized press and several crop groups, both in the cut flowers sector and in the greenhouse vegetables.

Figure 3.2. Involved growers visit the trial greenhouses ensuring the crop is cultivated as in practice prior to a regular stakeholders meeting.

Additional funding was provided by another supplier of Diffuse Glass, Guardian, who supplied a glass very similar to the one implemented in this experiment.

Short after the start of the rose experiment, an experiment with tomatoes started under glass of several diffusely levels with funding by the Dutch Ministry of Ministery of Economics, Agriculture and Innovation, the Dutch Horticultural Board, a diffuse glass supplier (Guardian), and In this tomato experiment, apart from the effects on production, extra information was collected to find out why diffuse glass has such a positive effect on production.

3.2.2 Feed-back to the developers

The glass suppliers where regularly updated about the results by means of short findings reports, but also by means of several short issues in the professional press.

The developers of the E-nose (Warwick HRI) received, fruit of the first growers meeting, a package of demands such a early detection system should meet in order to be successfully implementable in a rose greenhouse.

As the first (not very encouraging) results were presented, growers belief in a system able to be implemented at short notice diminished. It turned out that some lack of accuracy would be acceptable, but speed as well as autonomy are not negotiable.

The improvements by the developers after the first feed-back showed an impressive improvement in detection accuracy. Improvements on the other two issues were achieved, but still not enough to allow practical implementation.
Future improvements of early detection systems by means of volatile detection must concentrate efforts towards a very fast air-suction and analysis as well on battery life increasing.

Feed-back to the Rockwool supplier that developed the smaller Rockwool blocks that save rockwork was provided directly through discussion during two visits to the trial; the economic and environmental results were supplied by e-mail.

3.3 Location Tuscany

As mentioned before, the location Tuscany replaced the location Morahalom in Hungary at a later stage in the project. With the replacement, the stakeholders gathered around the trial were lost. The previous efforts done within WP6 to organize stakeholders around the trials were useless in Italy.

However, the problematics were similar to both countries, and that is why, despite this disadvantageous start, the researchers of UNIPI managed to organize a small stakeholders group around the implementation trial of the closed loop fertigation system.

3.3.1 Stakeholder involvement

The trial has involved a number of stakeholders for the follow up and discussions.

- The operation's owner and neighboring growers
- A researcher from UNIPI
- A representative of the regional extension office (ARSIA, Regione Toscana)
- An agricultural consultant (Dr. Silvio Fritegotto)
- A representative of an experimental center, Centro Sperimentale Vivaismo from Pistoia
- An irrigation company (Guastapaglia Irrigazione, Pescia, PT, Italy)

The group meets with a frequency of about five months and in particular at the starting and ending of each growing cycle.

Some results, about the possible effects of the use of closed system were also presented to the growers and stakeholder, in a technical workshop organized by UNIPI in October 2011 in Sicily, the most important Italian regions for the tomato greenhouse production. Local stakeholders were hugely interested on the closed-loop system and on the fertigation management procedures, since the average leaching fraction ranges from 30 to 40% due to the low irrigation water quality: in this situation, the use of a closed system could be a convenient option.

Thanks to the organization of the professor Ombodi Attile for the Szent István University (Godollo, Hungary), the possibility to use a closed loop system was presented also at the local stakeholders in Hungary, during a Congress held on the 28th June at Szentes, Hungary.

3.3.2 Feed-back to developers

The group of local stakeholders evaluated positively the adoption of the closed-loop system but at the end of the first growing cycle, they objected to be very much afraid of the potentially increased occurrence of root-borne diseases.
That is why, at the end of the second cycle samples were taken for pathogen analysis. Despite the absence of any pathogens in the drainage water and in the slabs, grower's fears could not be taken away. Also, growers are concerned about the relatively high investment costs. So, the application of closed growing technology is not foreseen for the near future, and the growers prefer to distribute the free-drainage leachate from the greenhouse to the crop grown in soil.

4 Test Site Almería, Spain. Effects of a NIR-absorbing plastic covering material. Tomato.

4.1 Objective

Evaluate the climate and the productive response of a tomato crop (long cycle) under two different covering materials: NIR absorbing film (with partial absorption of the NIR radiation) and a control film (standard covering material used in Almería greenhouses)

4.2 Background

In some geographical areas the reduction of the non luminous solar thermal energy transmission (NIR= near infra red radiation) into the greenhouse, which is the one ranging from 760 and 2500 nm approximately, can be advisable, at least during certain periods of the growing cycle. It is quite frequent to avoid the excessive heating of the greenhouse using shading screens inside the greenhouse or by means of whitening of the plastic film by applying a whitening product over the external layer of the cover. Both solutions have a negative effect: they decrease the NIR transmission, but they also decrease the transmission of PAR radiation (400-700 nm), which is precisely the radiation that plants require for photosynthesis and that should always be maintained as high as possible.

There are different alternatives that can be applied to flexible greenhouse film covers which involve the addition of interference pigments as additives in the film formulations, which cause a reflection or absorption of the NIR radiation.

The present work is enshrined within the Euphoros European project. Previous to the field test, simulations have been carried by WUR with the simulation software (KASPRO), fed by meteorological data from Almería (EEFC meteorological data) with optical data for different NIR absorbing materials provided by CIBA. The simulations showed that the NIR absorbing materials were in principle, able to exclude a part of the incident solar energy. However, their effect seemed limited, because part of the absorbed energy was transmitted to the interior of the greenhouse by convection, and in principle, reflection instead of absorption seems a more favourable option. A good NIR filtering material must exclude a high level of NIR, because the leaves of the crop are by themselves a good reflector of NIR (45%). The material must also affect as little as possible the transmission within the PAR range. Therefore, from the set of materials simulated, the best prototype was chosen (maximum NIR absorption with least possible PAR reduction) and manufactured to be tested at the EEFC facilities.

4.3 Materials and methods

During the 2010/2011 growing season, a field trial has been performed in two identical adjacent greenhouse modules of 1,200 m^2 area each. Each greenhouse compartment (Figure 4.1) has three asymmetric curved shape modules of metal structure, with a ridge height of 5.4 m and gutter height of 3.4 m. The south wall has a sidewall rolling vent and each module has a roof vent oriented south. The greenhouse compartment orientation was east-west. The vents were implemented with a 20*10 threads cm^{-1} anti insect screen.

The crop was grown in a perlite bags (third year of use), of 40 l capacity, of the B-12 grain size (particles of 0-5 mm of Ø), laid over expanded polystyrene channels. The orientation of the crop rows was north-south.

Each compartment has 22 crop rows, with 16 perlite bags per row with two plants per bag.

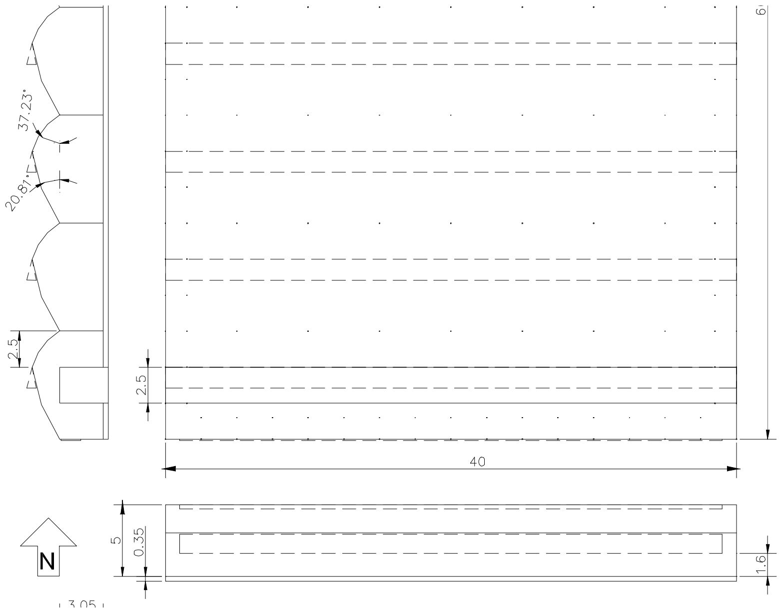


Figure 4.1.- Structure and dimensions of the experimental greenhouse compartments

The separation between crop rows was 1.66 m and 1.5 m between the centres of the growing bags. The tomato crop was transplanted on September 6th 2010, cultivar Ventero (Figure 4.2), with a plant density of 1.6 plants m^{-2}. Previous to the transplant both greenhouses were whitened (10th August) to ensure the survival of the seedlings under the harsh conditions of Almería during this month, using the same dose for both greenhouses, which involved that under the NIR absorbing film an extra NIR reflection was added. Whitening was washed away during the 5th/6th of October for the NIR absorbing greenhouse and the control respectively.

Figure 4.2. Truss tomato crop (cv. Ventero). Crop was pollinated with bumble bees (Bombus terrestris).

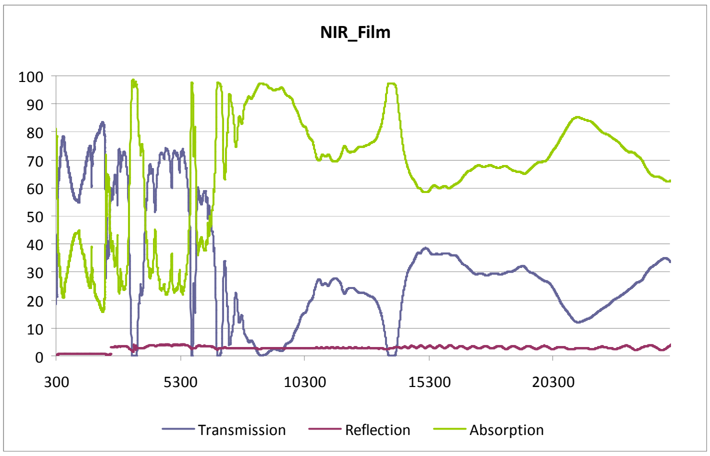
In each greenhouse a demand tray and a drainage tray were used to control the irrigation. Both trays had two growing bags, with four plants each. On a daily basis, the percentage of drainage of the crop and pH and EC were monitored.

Two treatments, one per greenhouse were established:

NIR_ film: greenhouse covered with the NIR absorption film prototype.

Control film: greenhouse covered with the standard three layers film used in Almería.

The covering materials were both installed in the two greenhouse compartments during August 2010. The optical characteristics of both materials, measured in a laboratory in WUR (The Netherlands) for different wavelengths are shown in Figure 4.3.



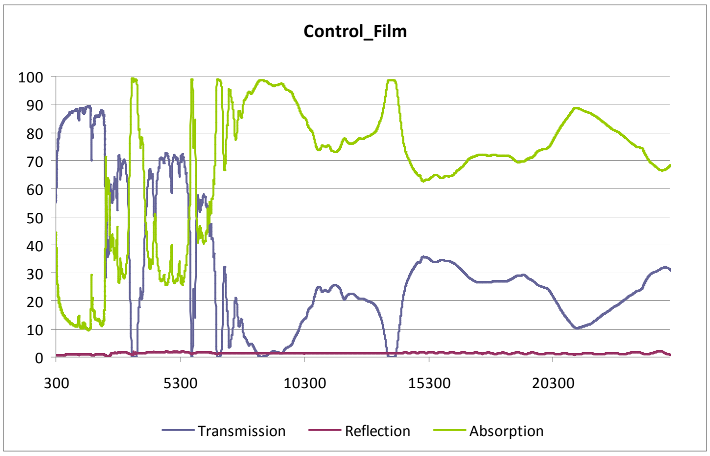


Figure 4.3. Transmission, reflection and absorption spectrum of the two tested materials: NIR_film and Control_film (laboratory data measured and provided by WUR).

The climate (opening and closing of the vents) was managed with a climate controller, by means of sensors located inside and outside the greenhouses.

4.3.1 Determinations

On each treatment, the following measurements and determinations were obtained:

The Ambient temperature and relative humidity: each compartment has 2 ventilated psicrometers (Pt-100) that read the air temperature (dry and wet bulb temperatures) from which humidity was calculated.

Global and PAR radiation were measured inside the greenhouse (Figure 4.5). Net radiation over the greenhouse cover was measured at a representative spot, over each greenhouse, and at a height of 50 cm over the cover, by means of a net radiometer .

The temperature of the greenhouse cover was measured by means of thermocouples. Cover temperature measurements were corrected to overcome the problem of direct radiation impinging on the sensor.

The exterior climate data were measured in a meteorological station located in the vicinity of the two experimental greenhouses (temperature, humidity, radiation and wind velocity and direction).

Crop production was measured in 5 repetitions per treatment and 8 plants per repetition (4 growing bags). Marketable and non-marketable yield were separately quantified.

Figure 4.5. Images of the sensors used in the greenhouses for climate monitoring.

4.4 Results

4.4.1 Climate

The average air temperature inside both greenhouses was very similar along the whole cycle (Table 1), with average values of 24 h of 17.5 ºC and 17.4 ºC for the NIR_film and Control_film respectively. Equally, the maximum temperature values were similar for both treatments, 40.9 ºC and 40.5 ºC, for the NIR_film vs. Control_film, respectively.

Table 1. Daily mean air temperature (ºC) 24h, day, night, maximum and minimum for the total cycle of crop.

	Air temperature (ºC)				
Treatment	**24h**	**Day time**	**Night**	**Maximum**	**Minimum**
NIR film	17.5	21.9	13.7	40.9	4.7
Control film	17.4	21.5	13.8	40.5	5
Exterior	15.5	17.8	13.5	30.2	3.3

Figure 4.6 shows the average ambient temperature (24 h) along the whole cycle, and again it shows the great similarity in the values, which obviously were consistently higher than the exterior ambient temperature.

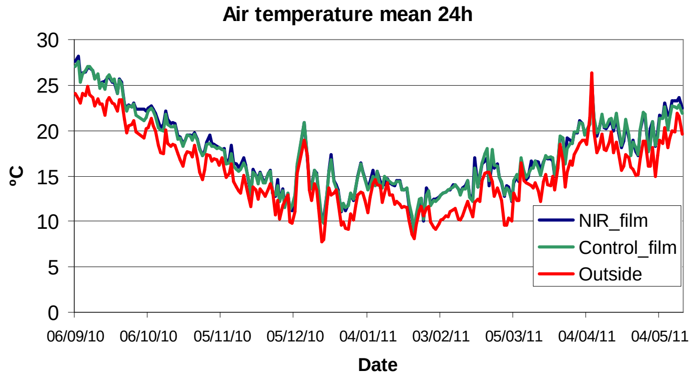


Figure 4.6. Daily mean 24h air temperature (ºC) in NIR_film, Control_film and outside.

The net radiation measured over the greenhouse cover (Figure 4.7) was slightly larger for the NIR_film treatment than in the Control_film. This may partially justify the absence of ambient temperature decrease expected inside the NIR_film greenhouse due to its NIR absorption effect (heat convection from the plastic into the greenhouse).

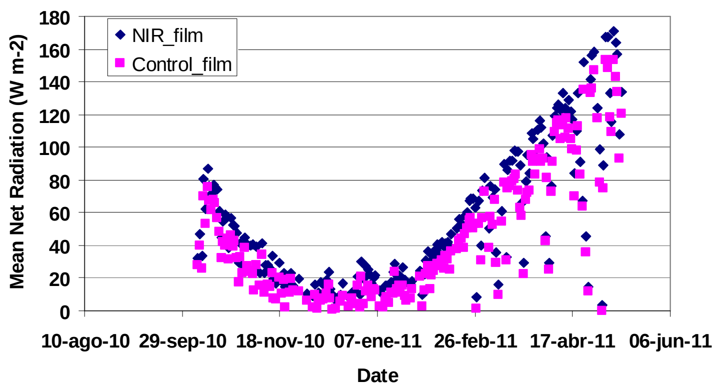


Figure 4.7. Daily mean net radiation (Wm^{-2}) over greenhouse for two treatments: NIR and Control.

Figure 4.8 shows the ambient temperature, cover temperature and radiation data along one day of the growing cycle (20/3/2011) for both treatments. The ambient temperature was similar both under the NIR_film and the Control_film greenhouse. The cover temperature was higher in the NIR film than in the Control_film, up to 10 ºC higher due to the higher absorption of the material within the NIR range.

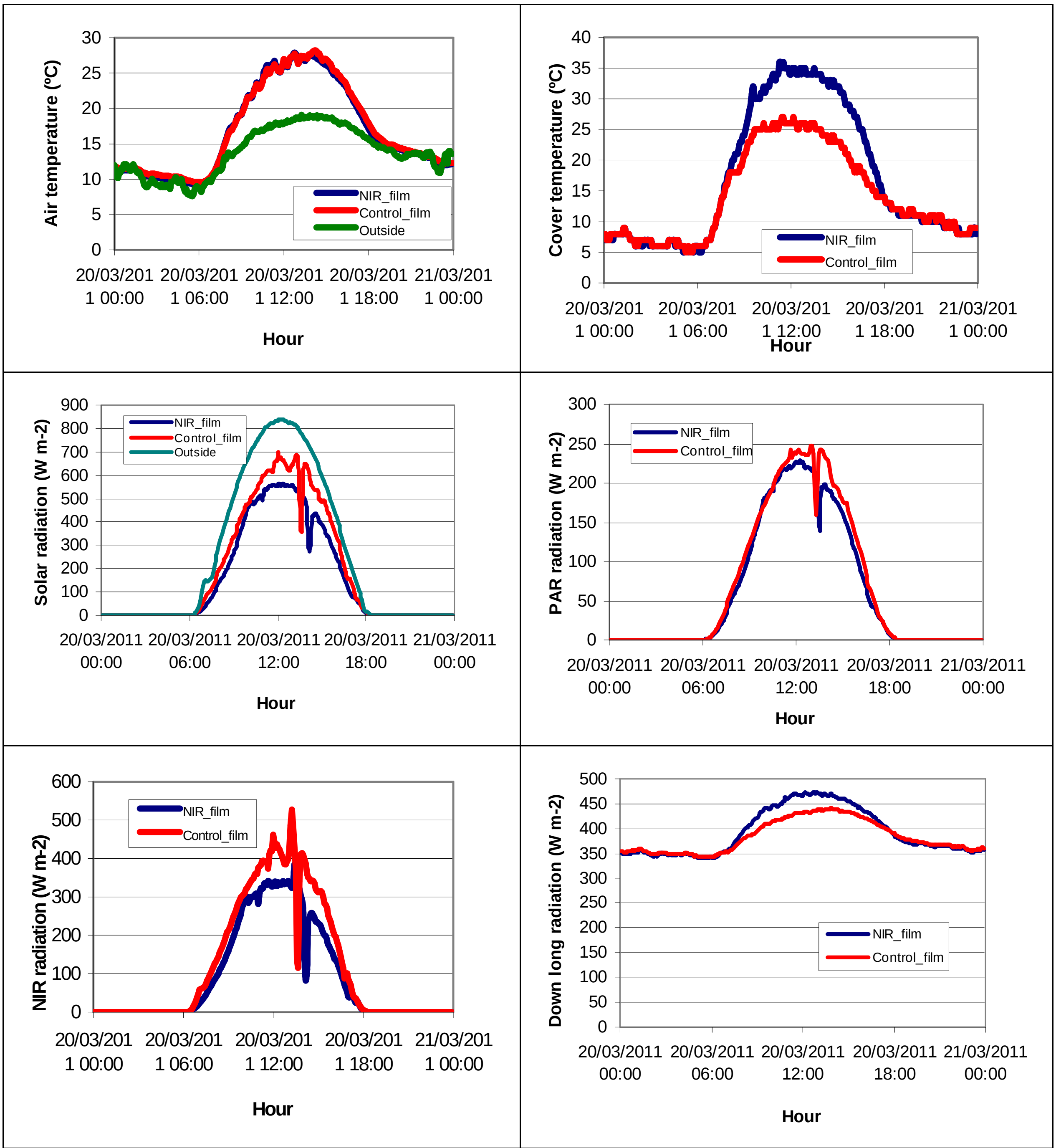


Figure 4.8 Air temperature, cover temperature and radiation for a day (20/03/2011) in both treatments.

Solar radiation and NIR radiation were lower under the NIR_film, as would be expected. However, the PAR radiation was also affected, being also lower under the NIR_film, a non desired side effect, due to its possible harmful repercussion on the crop yield. Regarding the long wave radiation, the NIR_film greenhouse emitted more, due to the higher temperature reached by the material, previously discussed.

4.4.2 Production

The total and marketable yields are shown in Figures 4.9 and 4.10. The marketable yield was higher in the Control_film greenhouse than in the NIR_film greenhouse. The difference in yield was found in the first quality fruits, 14.49 kg m^{-2} and 12.67 kg m^{-2}, respectively. Second quality production was significantly lower and similar for both treatments.

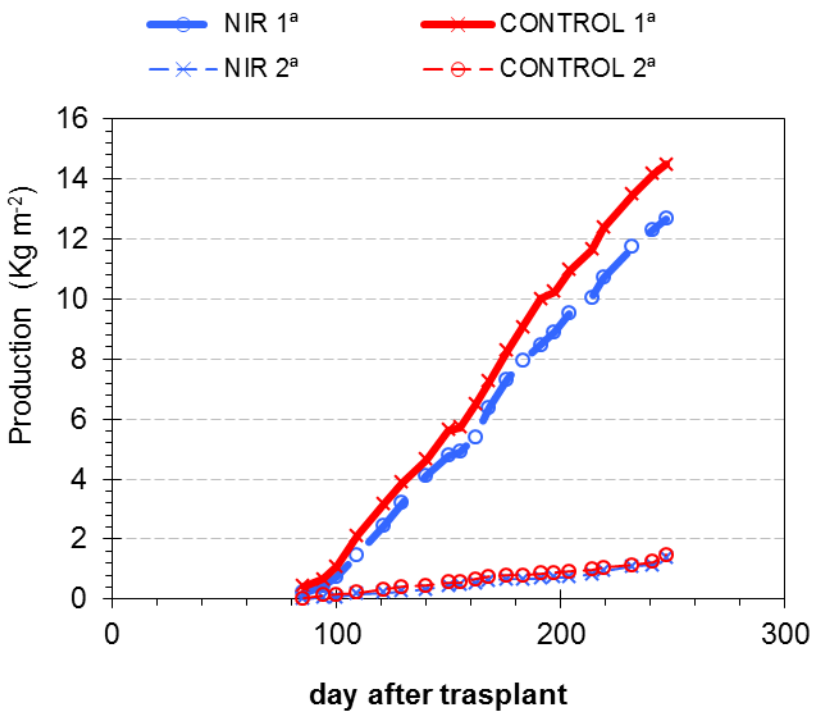


Figure 4.9 Accumulated first quality and second quality marketable yield along the growing cycle for each treatment.

Differences were also found in the number of harvested trusses, being 16.4 and 15.1 for the Control_film and NIR_film, respectively (Figure 7).

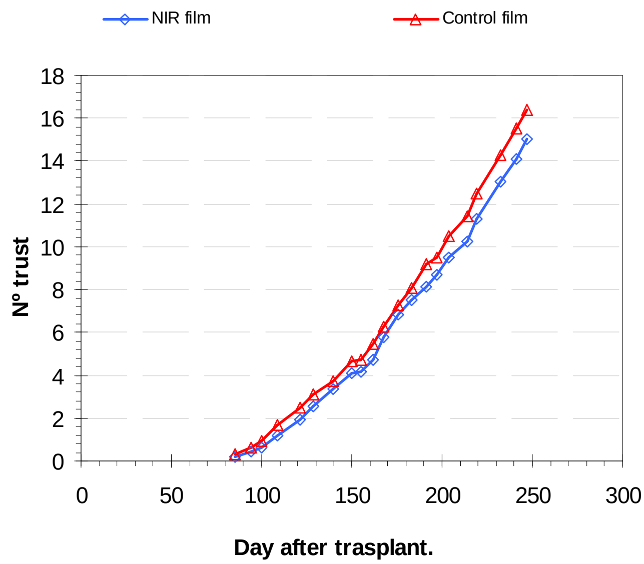


Figure 4.10. Accumulated number of trusses harvested for each treatment along the growing cycle.

Besides, it was visually observed along the trial that less condensation occurred in the inner layer of the NIR_film greenhouse than in the Control-film in the early mornings (figure 4.11), which could have been caused by the higher temperature reached by this film

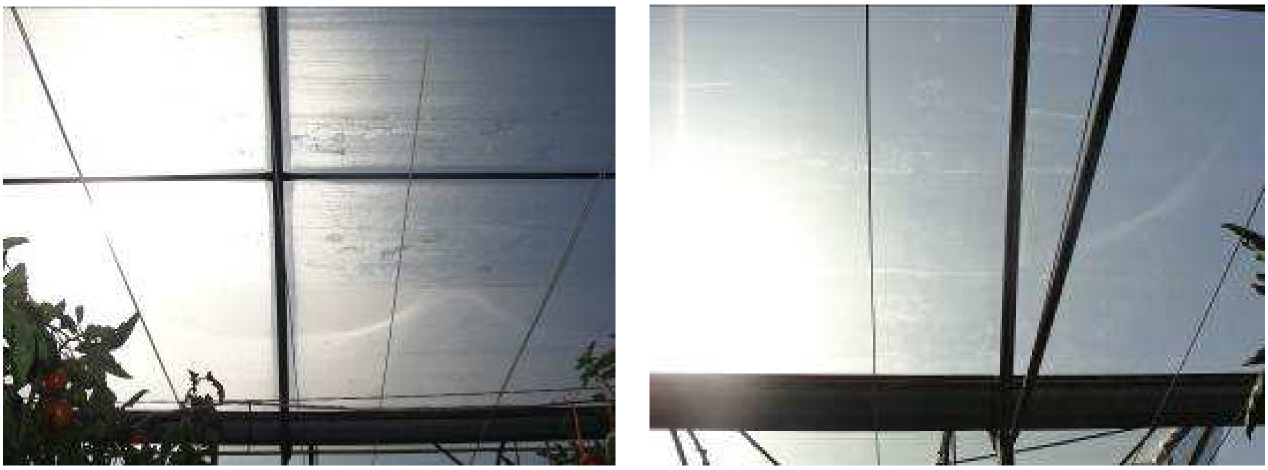


Figure 4.11. Left, control film showing condensation in the morning, and right, NIR_film, without condensation.

4.5 Conclusions NIR-absorbing plastic cover

-The evaluated NIR film did not reduce the air temperature as compared to the control film. Net radiation balance was slightly higher in the NIR film than in the control film.

-The NIR blocking film caused a PAR reduction close to 15% .

-Fruit production in the NIR-film was also nearly 15% lower than in the control film, approximately the same as the loss in PAR radiation. Future developments in NIR blocking film greenhouse cover materials need to be adressed towards the use of additives that Reflect NIR radiation instead of Absorbing it (as the one used for the trial). Specially in warm geographic areas it is a priority to reduce the air temperature during a great part of the time;

- . The additives, however, should not reduce the transmisivity in the PAR.

4.1 References NIR-absorbing plastic cover

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5 Test Site Bleiswijk, The Netherlands. Effects of a Diffuse Glass Cover. Roses.

5.1 Introduction

5.1.1 Light distribution in glasshouses

Light is not evenly distributed in glass greenhouses. In particular, tall crops such as cucumber, sweet pepper and tomato have a high leaf area index and intercept a large quantity of light with the upper leaves, while the middle and lower leaves receive much less light and contribute very little to photosynthesis, growth, and in the end, production. As the uppermost leaves may often be light-saturated, it can be argued that a more uniform light distribution would result in higher overall assimilation. At least, if the lowermost leaves have enough photosynthetic capacity to take advantage of the additional light. This was proven by Hovi et al. (2004) who showed that a higher amount of artificial light within a crop–achieved by inter-lighting–significantly increased photosynthesis of the lower leaves of cucumber.

5.1.2 Diffuse light

Uniformity of light distribution can be realized by diffuse light. From earlier investigations in forests (Farquhar and Roderick, 2003; Gu et al., 2003), apple trees (Lakso and Mussleman, 1976) and grass canopies (Sheehy and Chapas, 1976) it is known that diffuse light is able to penetrate deeper into a plant canopy in comparison to direct light and that photosynthesis in forests is increased by diffuse light. There are also indications that plants have developed mechanisms to use diffuse light more efficiently (De Lucia et al., 1996; Vogelmann, 1996).

Diffuse light can have advantages also for greenhouse cultivation of young plants and small plants like pot plants, as it could improve the sub-optimal horizontal light distribution. Shadows cast from the greenhouse construction have a negative influence on the plant production. In order to realize a uniform production, the light distribution has to be uniform over the whole canopy. This can be achieved by diffuse light. Light can be made diffuse by modern covering materials (Hemming et al., 2008B). Such materials contain pigments, macro- or microstructures, which are able to transform a fraction of the direct light into diffuse light, this fraction is called "the haze factor" and quantifies the diffusive effect of the material. Depending on the design of the structure the incoming light scatters, the angle of incidence is changed. Efficient structures make the light diffuse without a significant reduction in light transmission. During the past six years Wageningen UR Greenhouse Horticulture has investigated the potential of diffuse covering materials used in Dutch greenhouses (Hemming at al., 2005A; Hemming at al., 2008B). The suitability of several greenhouse covering materials and their optical properties (PAR transmission: τ–direct and τ–diffuse, haze) was investigated in laboratories as well as in practice. Both in cucumber and potted plant crops (Hemming at al., 2005B; Hemming at al., 2008A) diffuse covers resulted in a more effective photosynthesis and better quality.

5.1.3 Potential of diffuse light for rose cultivation

The many positive effects seen with other crops, gave good reasons to believe this new materials could also have a great impact in the cultivation of the most important and most energy-demanding ornamental crop in The Netherlands: roses. If more production can be achieved with the same amount of outside radiation, there is an energy saving potential in terms of electricity for the lamps that can pay back for the extra costs of the material. Inversely, if more flowers can be produced with the same energy-input, an increase of the energetic efficiency is to be realised (more output per KWh).

The rose crop has a totally different plant architecture as the previously investigated vegetable crops, so also from the point of view of light interception by the crop and to learn more about diffuse light it was desirable to test these materials with roses.

Moreover, in summer time rose crops are often shaded, as very high light intensities (from the sun) in combination with the related high crop temperatures and VPD, can also negatively affect photosynthesis (Dieleman et al., 2007). However, the main reason for shading is to avoid burning damage of leafs and flower buds (the leaves are part of the marketable value; the flower size and shape must be in balance with the stem size and length). A diffuse AR-coated glass cover has the potential to slightly reduce the greenhouse temperature and to reduce sudden high levels or irradiation at bud level, thus potentially reducing the need for screening. Less screening hours automatically mean more light in the greenhouse, and presumably more production.

5.1.4 This experiment

Modifying float glass to obtain a light diffusive material by means of light-dispersive structures resulted so far in a decrease in light transmission. However, the coating of both glass surfaces with an anti-reflective (AR) coating, can lead to an increase of the light transmission through the glass of as much as 8% (Kempkes et al., 2009). Within the project EUPHOROS , the in Letland operating company GroGlass developed a special AR coating for both sides of the glass. By using the coating on an existing diffuse material, Vetrasol 503, it was possible to increase the light transmission of the diffusive material. It was also proven that the surface structure of this material almost totally counteracts the light transmission loss that occurs when water damp from the greenhouse condensates against the glass (Stanghellini et al., 2010).
The material seemed so interesting for rose cultivation, that in consultation with stakeholders (see Chapter 2 and 3 of this report), it was decided to test it within WP6 of the European project EUPHOROS.

However, within EUPHOROS there was insufficient budget for a proper test with a reference greenhouse with normal float (glass). Additional funding was obtained from the Public- Private Dutch research program "greenhouse as source of energy", thanks to the great interest from representatives of the Dutch Rose Growers for the material, as well as from the coordinators of the research program (The Ministry of Economy, Agriculture and Innovation, and the Dutch Horticultural Board). Glass suppliers and importers and a Rockwool supplier contributed to the project by a free of charge supply of the necessary materials, including transport.

Short before the plants should be transferred to the trial and the reference compartment, we were approached by a representative of Guardian, who wanted to perform a trial to see the effects of their own glass type on the production and quality of roses. This resulted in a privately financed third greenhouse compartment covered with glass of similar characteristics as the trial greenhouse, but with a single side AR coating (on the outside of the greenhouse). In this third greenhouse, also the climate was managed in a (heating) energy-saving manner. Because of the different climate management, we do not show the results in this report, unless they add relevant information.

The trial set-up, research method and results obtained in this comparative experiment of two greenhouse glass covers are presented in the following sub-chapters. The consequences of this results for the environment and the economics of rose cultivation are briefly discusses, as they have been extensively treated in Deliverable 13 of the Euphoros project (Montero et al., 2011).

5.2 Materials and methods

5.2.1 Location and orientation

The experiment was carried out in 2 compartments (144 m^2) of a Venlo-type glasshouse, located in Bleiswijk (52°N, 4.5°E), western part of Holland. The greenhouse is E–W oriented. Each compartment is composed of 2 spans, each with north-south width of 4.8 m and east-west length of 15 m. The height of the gutter is 5.5 m and the roof angle is 22°. The soil surface of each compartment is covered with anti-weed sheet, with the exception of a 1.2 m wide, concrete path situated along the entrance of the compartment. Each span is equipped with continuous roof vents, over the whole length, the flaps are 1.3 m wide.

5.2.2 Glass properties

One compartment is covered with standard glass whereas the second compartment is covered (side walls included) with a custom-made glass with the following characteristics: diffuse glass (Vetrasol 503, supplied by HoGla and Glascom), with an Anti-Reflection coating on both sides (specially applied by GroGlass). The glass has in one side a prismatic structure, that makes the light in the greenhouse diffuse and reduces the transparency of the glass (figure 5.2), which is placed, after measuring that it results in a higher transmission, towards **the inside** of the greenhouse compartment. In Table 5.1 the overall properties of these glasses and of the compartments are shown. Figure 5.1 shows the light transmission along the light spectrum between the wave lengths of 300 and 1000 nm.

Table 5.1. Transmission (τ perpendicular and hemispheric) and haze of the two cover materials and the overall transmission of the greenhouse compartment covered with each one (measured at three moments of the year).

Material	τ Perpendicular	τ Hemispheric	Haze	τ Compartment		
Reference	90 %	82 %	0 %	61 %	55 %	61 %
Diffuse AR	93 %	83 %	73 %	60 %	55 %	63 %

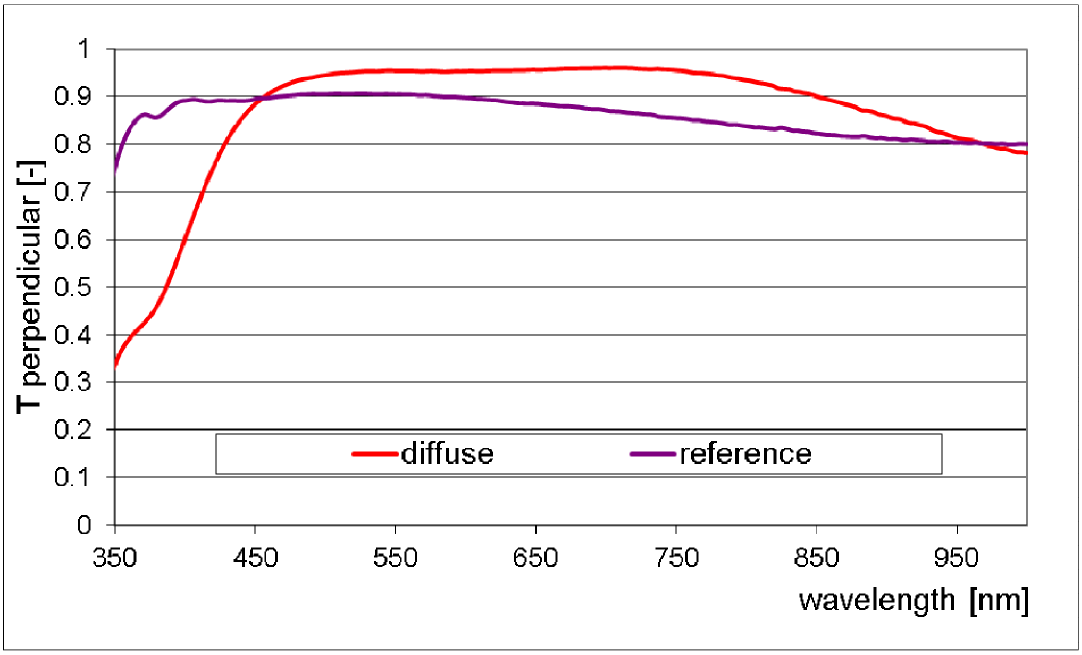

Figure 5.1: Light transmission of the glass (laboratory measurements) as compared to the standard (normal float) glass.

Figure 5.2: the glass has a prismatic structure that makes the light diffuse and reduces the apparent transparency of the glass. Picture left: during the replacement (august 2010), picture right, November 2010, during cultivation.

5.2.3 Plant material

The rose plants (Rosa hybrida cultivar 'Red Naomi!') were propagated by cuttings using the Synchronization Method (Van Telgen et al., 2003) of Wageningen UR Glasshouse Horticulture in Rockwool plugs (Grodan) and once rooted they were planted in May 28th in SPU (single production units) Rockwool blocks (Grodan) of 24x20x7,5 cm with 2 plants per block (Figure 5.3). The used system saves 20% substrate compared to the traditional, or standard system with 4 blocks (one plant each) on a slab. The extended propagation method (figure 5.4) allowed transport of the productive plants (figure 5.5) on August 26th to the experimental compartments with respectively clear and diffuse glass and placed on E–W oriented gutters, with a plant density of 6.2 plants/m^2.

Figure 5.3 Plants directly after planting in Grodan SPU   Figure 5.4: Plants during extended propagation

Figure 5.5: Productive plants after extended propagation (left) are being transferred to the trial compartments (right).

5.2.4 Cultivation method

The plants were grown following the 'bending' technique (de Hoog et al., 2000), which consists in bending the primary shoot at the beginning of the cultivation, and during cultivation all stems are bent when they are of unmarketable quality or not useful to flower production (i.e. blind shoots). In such a way, the crop consists of two different types of canopy: a horizontal or "bent" canopy, that could be considered a sort of assimilates "factory" for the plant, providing nutrients to the developing shoots. This constitute the vertical canopy of harvestable stems, that take over the assimilates producing tasks as the leafs unfold and turn green. The resulting particular crop architecture, nowadays world-wide common practice in rose cultivation, is shown in Figure 5.6.

5.2.5 Water and nutrients

The plants were irrigated by means of a drip system, which was automatically controlled by a fertigation computer. Each SPU (2 plants) had one 2 litre/hour dripper. Water supply scheduling was based on drain percentage, outside solar radiation and crop stage. A drain water percentage was targeted of around 50%; drainage to be obtained after the second watering in the morning. The nutritive solution used was the standard solution for Rose on Rockwool (De Kreij et al., 1997), as shown in table 2. The solution was adjusted by means of monthly laboratory analysis. The main adjustments consisted in adjustments of ammonium concentration, as the crop stage influenced greatly the pH of the solution.

Table 5.2: composition of the nutritive solution

Macro Elements	NH_4	K	Ca	Mg	NO_3	SO_4
Concentration (mmol/l)	1,5	4,5	3,25	1,125	11	1,25
Micro Elements	Fe	Mn	Zn	B	Cu	Mo
Concentration *(µmol/l)*	25	5	3,5	12	0,75	0,5
	EC	pH				
	1,6	5,5				

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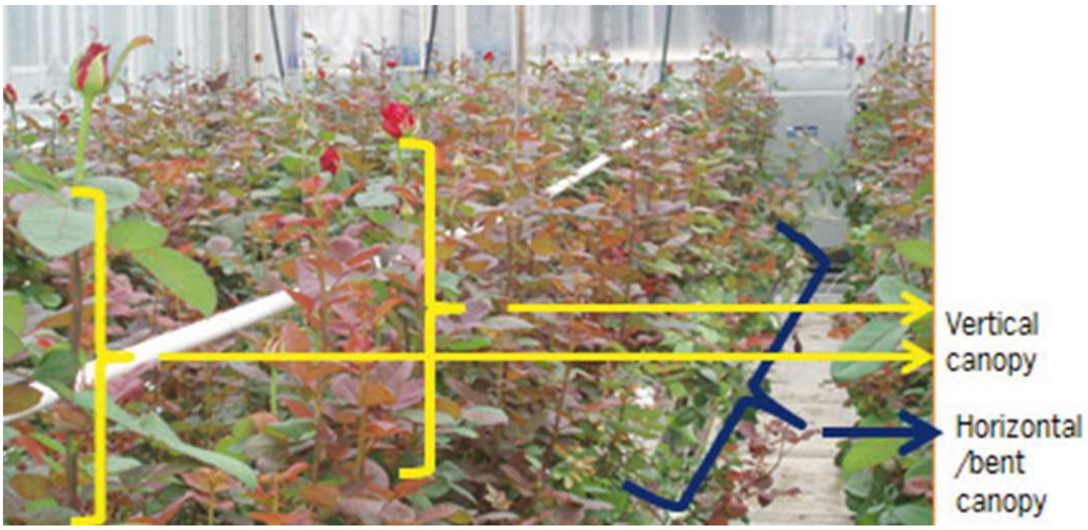

Figure 5.6. The structure of a rose crop showing the two canopy planes as a result of the bending method

5.2.6 Climate control

Climate control was managed in close consultation with growers of the cultivated variety, in order to ensure commercially representative growth conditions. The only difference concerned the use of a minimum-heat pipe temperature, which is common in Dutch commercial cultivation (heat is a by-product of the electricity production due to the co-generation system). In this project, is was aimed to use the heating only if needed: a 35 oC pipe temperature was allowed in winter time (December, January and February) between 19:30 and 21 hours, to avoid a sharp temperature decrease as a consequence of switching off the lamps.
The heat was also used to avoid the greenhouse temperature to decrease below the minimum accepted night temperature (16o C) and to avoid the RH in the greenhouse to increase above 80-85%.

5.2.6.1 Shade screens

In spring /summer shade screens (LS XLS 13 F Ultra Firebreak) with a screening of 32% and an energy saving capacity of 15%, closed according to commercial practice when the outside radiation exceeded 600 W/m^2 in the reference (clear glass compartment). In the trial compartment (with diffuse AR glass cover) in consultation with the growers we initially decided to keep the screens permanently open.

However, damage to the crop occurred in march (petal blueing), so a value for screening was fixed on 700 W/m^2 by means of some “trial and error” during the first sunny days in early spring.

5.2.6.2 CO_2

CO_2 was supplied by means of injection during daytime or if the artificial lighting was switched on to achieve an average of 800-1000 ppm. Maximum CO_2 supply is limited, as in normal commercial practice, to 350 Kg/ha per hour. In summer, due to the required ventilation to maintain the greenhouse temperature, the target values were not always achieved.
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5.2.6.3 Temperature

Set average temperatures were19-20 degrees in autumn and winter and 21-22 degrees in spring and summer. Minimum night temperature was set at 15°C.

5.2.6.4 Light

Artificial lights (170 μmol/m^2/s) were used during the night period and whenever the outside radiation dropped below 250 W/ m^2 up to a maximum of 18 hours per day. A dark period of 6 hours a day was maintained (from sunset to 6 hours after sunset).

5.2.6.5 RV and fogging

Fogging was applied to the greenhouse whenever the Relative Humidity of the greenhouse reached a value lower than 65% and stopped when it reached 75At RV’s higher than 80%, is was allowed to ventilate at night with a narrow window opening.

5.2.6.6 Climate data recording

Throughout the growth period, climatic data were recorded at 5 minute intervals by the greenhouse control computer system. The inside air temperature, relative humidity, water vapour deficit and CO_2 concentration were recorded by means of a measuring box, located 1.3 m above the ground at the height of the harvestable stems. The inside photosynthetic active radiation was measured with a Quantum sensor located just above the crop. Outside air temperature, RH, solar radiation, wind speed and wind direction were recorded automatically by means of a weather station. An infrared camera monitored the crop temperature.

5.2.6.6.1 Registration of the (heat) energy consumption

Energy meters have been installed in both heating nets. The meter-readings were not coupled to an automated data acquisition system, and were recorded daily by hand. Besides, as the temperatures of the heating pipes were automatically registered at 5 minute intervals, it was possible to achieve an indirect measurement of the energy consumption for heating.

5.2.7 Pest and disease management

Pest management was integrated (IPM): as much as possible by means of biological agents against the most common pests: red spider mites, white flies, Californian thrips. The greenhouse is closely monitored by scouts by means of sticky traps, direct crop observations and leaf samples.

The colonization of the crop by new, natural enemies is followed in a separate crop health project (Pijnakker et al., 2012). The presence of these new predators was of great help to maintain the pest pressure low during the whole cultivation.
Pest for which no effective biological control agents is available, such as caterpillars, echinothrips and aphids, were controlled by means of compatible chemicals.

Disease (the only occurring disease was powdery mildew *Sphaeroteca pannosa*) was scored once every two weeks and controlled chemically.

5.2.8 Harvest and data collection

From the second production flush on (starting on the 16th of September 2010), flower production of 6 fields per greenhouse (total assessment surface +/- 50 m^2) was registered. Flowers were harvested daily in the commercial bud stage commercially accepted by the Dutch Auctions for this variety (See figure. 5.7) Each harvested stem was counted, weighted, stem and bud length were measured and if applicable, quality remarks susceptible to reduce the market value (such as blue edges on the petals, turning hearts, mildew spots, burned leave tips, etc.) were recorded.

5.2.9 Additional measurements

Next to the normal daily harvest data, incidental or additional measurements were taken in order to contribute to other developments within Euphoros (example: crop transpiration, disease incidence), or to a better understanding of the effects of diffuse light for the crop.

5.2.9.1 Crop transpiration

From November 2011 weighting gutters were installed in both greenhouses to allow monitoring of water supply, drainage and transpiration by the crop, in order to be able to validate the Stanghellini model. More details about this system in chapter 2.2.5 of this report.

5.2.9.2 Light interception by the crop

In January and in April a Sun-scan meter was used to measure the light intercepted by the crop at different heights of the canopy. .The light level received at the top of the vertical canopy (the buds) was set at 100%; the light measured at lower heights was expressed as a percentage of the light intensity at bud level.

5.2.9.3 Leaf photosynthesis

In November 2010, January and May 2011 a Li-Cor Photosynthesis meter was used to measure the potential leaf photosynthesis by the plants. Light-response curves were produced by means of measurements performed at several light intensities of three mature leaves per greenhouse and per canopy type (horizontal and vertical).

5.2.9.4 Post-harvest quality

Attention was paid also to the post-harvest quality of the harvested roses between January and April. For this purpose, 20 flowers per greenhouse were randomly selected at various harvest data, wrapped in paper, placed in water containing a post-harvest treatment for roses (Florissant 600, 10 ml/l) and kept overnight in this solution in a cold room at 4 ºC. After this post-harvest treatment, the flowers were transferred to a flower vase life testing room (see figure 5.8) with conditions as internationally agreed for this purpose: 20°C, 60% RH, 12h light per day at 14µmol/m^2.s (Reid and Kofranek 1981), and placed, after re-cutting the stem ends, in individual vases containing tap water for vase life evaluation. Vase life is terminated when due to wilting, flaccidness, bent-neck or any other senesce symptoms, the ornamental value of the flowers has decreased to a level in which the average consumer would discard the flowers. Vase life is defined as "the number of days from placing in the vase in the flower testing room (day 0) to the day in which the average consumer would not keep the flowers any longer in the vase.

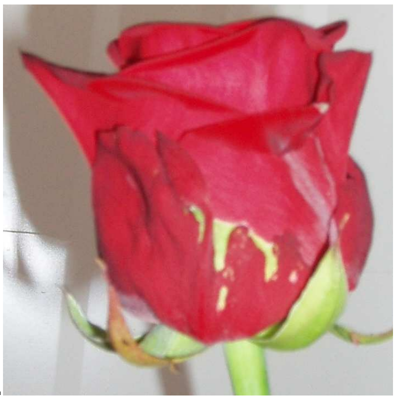

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Figure 5.7. Bud stage at harvest Red Naomi

Figure 5.8: Post-harvest quality evaluation in vase life testing room

5.2.9.5 Flower bud temperature

Flower bud temperature was measured at different days in February and March 2011 by means of a hand-held infrared meter. from 60 to 150 almost harvest ripe buds. Measurements were performedat different crop, greenhouse and weather conditions (sunny and clouded, with and without lamps switched on, with and without sunscreens, with and without heating, at the sunny and the shadowed side of the bud).
Incidentally, during two whole different days the bud temperature was monitored with the aid of a thermography film camera, to see the daily patterns and to visualize the effect of cooling actions.

5.2.9.6 Leaf tip burning

Leaf tips of non-mature leaves (red colored leaves) showed some burning symptoms after the first days of high light incidence in February. To find out whether the diffuse glass with AR coating could prevent this deleterious effect on the crop of high light intensity, the number of burnt leaves was counted in both greenhouses between March and May.

5.3 Results and discussion

5.3.1 Effects on climate in the greenhouse

Due to the different greenhouse cover the following effects were observed on the greenhouse climate:

a. the light in the greenhouse showed a smoother line on sunny days (figure 5.9);
b. the greenhouse temperature did not differ in both greenhouses
c. the greenhouse cover did not influence the energy consumption for heating in the greenhouse
d. the total summed light received per day in the trial greenhouse was higher than in the reference

This last effect was caused by differences in screening regime, an indirect effect of the diffuse glass cover used.

These 4 effects on climate are explained and discussed further below.

5.3.1.1 Light in the greenhouse

The diffuse greenhouse cover smoothed the ups and downs that are measured in the reference greenhouse, so with a net higher day average irradiation, the maximum recorded values were lower. The anti reflection properties of the cover probably contribute greatly to this effect. This is to see in the same figure 5.9, when we compare the covers with anti-reflection on one side (purple line, greenhouse 6.05, with glass supplied by Guardian) and the cover with anti-reflection coating in both sides of the glass (blue line, greenhouse 6.07, with glass coated by GroGlass). In the figure, the outside radiation (red line) shows a very stable normal distributed line. The height of the red curve is lower than inside, but this is due to the different measuring units used: the outside radiation is measured in Watt/m^2 total radiation, while inside it is the Photosynthetic Active Radiation (part of the total), and it is measured in µmol/m^{2}s.)

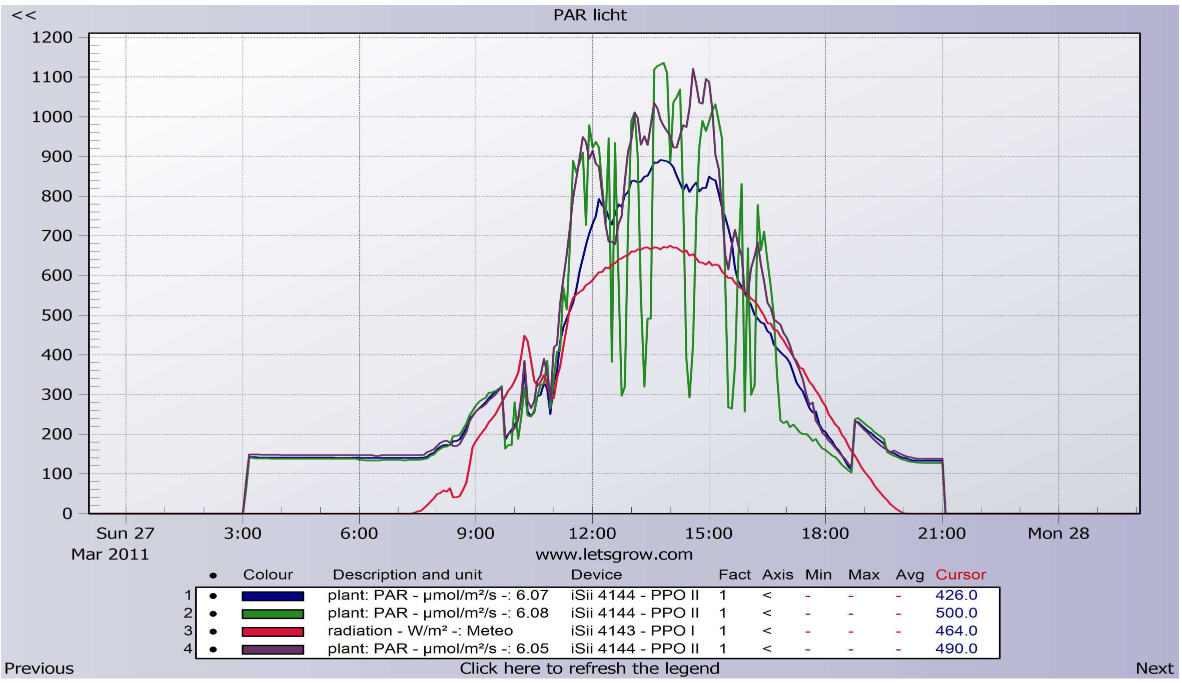

Figure 5.9: Light in three greenhouses with a different glass cover on a sunny day. The red line is the outside radiation, the green line the light in the reference greenhouse. The purple line shows the light in a third greenhouse (diffuse, one side Anti Reflection coating) and the blue line is the greenhouse with diffuse glass with double sided Anti Reflection coating by GroGlass.

5.3.1.2 Temperature

Although it feels cooler in the greenhouse with diffuse glass, the average day temperature was the same in both greenhouses over the total trial period 21,2°C (see figure 5.10, left), where the daytime temperature averaged 22,4°C in de reference greenhouse and 22,3°C in the diffuse AR greenhouse (figure 5.10, right). Average night temperature was 18,1°C for both compartments.

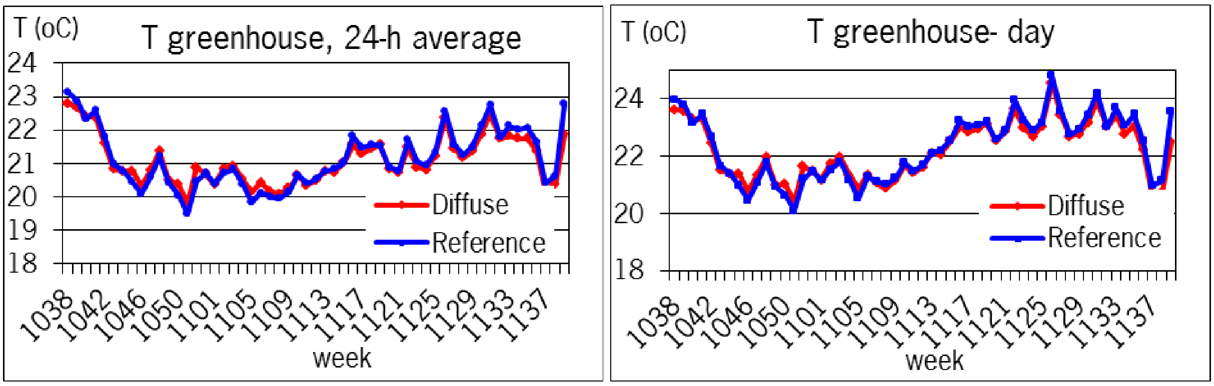

Figure 5.10 left, average 24-hour temperature in both greenhouses, and right, during daytime.

5.3.1.3 Energy consumption

The heat demand of the greenhouses was about 550 MJ / m^2 in greenhouses with a small difference of 1% less in the diffuse greenhouse. This difference is too small to be attributed to the greenhouse cover and can be due to small differences in adjustment of heating and ventilation set points.
The measured energy consumption between December 22 and Augustus 19 is 360 and 370 MJ/m^2 for respectively the diffuse greenhouse and the reference greenhouse. That is a difference of 4% less energy used in the Diffuse AR greenhouse to be attributed to the absence of a minimum heat pipe constantly at night, and to a slight malfunction of a window in that period.

5.3.1.4 Daily light integral

Figure 5.9 showed the light in the greenhouses on the 27th of March. At that date the outside radiation reached a maximum of 675 W/m^2, so exceeding the threshold held in practice by growers for the use of the sun screen. Between 13:00 and 15:30 hours, this corresponded with PAR levels inside the greenhouse above the damage threshold of 1000 µmol/m^2s known by growers. And indeed, the harvest of the day after showed blue edges on the petals of a few flowers.
From the 20th of March we experimented with different threshold light intensities for screening and then counted the number of flowers with blue edges that followed a certain threshold.
From the 9th of April, shade screens were used in both greenhouses, with the following thresholds:

in the reference greenhouse the commercially used value of 600 W/m^2
in the trial greenhouse (diffuse, AR) 700 W/m^2

This difference in screening threshold lead to a different number of screening hours per greenhouse, and consequently to a higher day light sum in the Diffuse AR greenhouse than in the reference (see table 5.3). The total difference in both greenhouses till august amounted 142 Mol. The difference includes the lamp light. In total, the lamps were switched on 4560 hour per greenhouse. ,. The contribution of the lamps to the total light in the greenhouses is shown in Figure 5.11 (right). In the darkest months it represented more than 50%. Weeks 20-28 in 2011 no artificial light was used.

Table 5.3. consequences of the shading threshold for the total light in both greenhouses

	Reference greenhouse (normal float)	**Trial Greenhouse (Diffuse AR glass)**
Shading threshold	600 W/m^2	700 W/m^2
Shadow hours (April-September.)	438 hours	285 hours
PAR Sum (Sept-Sept)	5361 Mol/m^2	5219 Mol/m^2
Extra PAR Diffuse AR compared to reference	0	142 Mol
Extra PAR Diffuse AR as % of total (reference =100)	100	102,72 %

Till the end of the experiment, the diffuse greenhouse received 2,7% more light than the reference greenhouse. If we consider the "light rule of thumb" (used in practice, and now a days being re-considered), by which 1% more light = 1% more production then this extra light sum achieved by the use of less hours of screening, would lead to a total production improvement in the diffuse+ AR glazed greenhouse of 2,7% as compared to the reference. See 5.3.2 for the effects on production.

The light in both greenhouses as measured along the year is shown in figure 5.11, left.

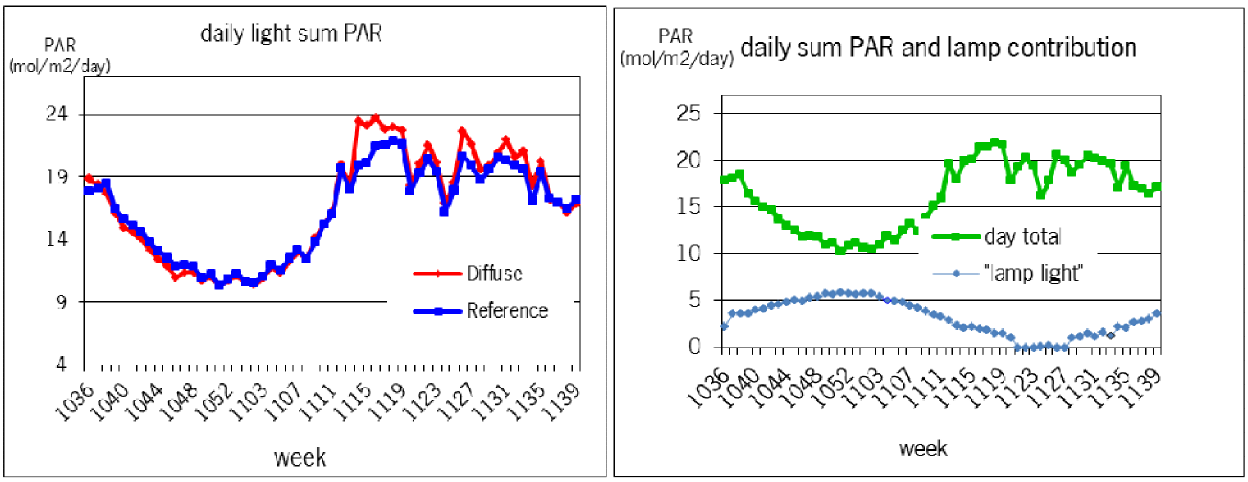

Figure 5.11 (left): Light sum in both greenhouses along the year, and right, contribution of the lamps to the total daylight sum.

5.3.2 Effects on flower production

The production results are shown in Fig. 5.12, cumulative production in weight, Fig.5.13, cumulative production in number of stems and Fig. 5.14, production in number of stems per week. The wave-pattern in the cumulative production line is due to the flush-effect in the crop; this is also the cause of the zig- zag pattern in the week-production; ideally, a constant production is harvested every week. Commercial growers use different tricks to avoid this pronounced flush effect, often by spread planting already at the beginning of a new cropping period (normally lasting 4 years). A young crop is more sensitive for the flush effect than an older crop; in figure 5.14 it is visible that the periods with little

production become shorter and the lowest production higher during the course of the experiment, as the crop grows older.
During the first autumn, presumably as a result of the cover properties, a slight difference in production was measured (2% more harvest weight and 1.5% more stems), but this difference disappeared in the winter. In winter, the influence of the glasshouse cover on the crop is apparently of little importance as in our latitude most of the natural light is already diffuse (> 75%), the predominant weather is cloudy, and the short days are compensated by artificial light, whose contribution to the daily light integral in the greenhouses is huge compared to the natural light (see figure 5.11, right).

From May onwards, the differences in screening regime applied since the beginning of april, led to differences in total light integral and a small production advantage appeared in the diffuse greenhouse compared to the reference. This advantage has resulted in total in 513 more stems harvested in the measuring fields in the diffuse greenhouse than in the reference greenhouse. This is 5,2% % more marketable flowers.

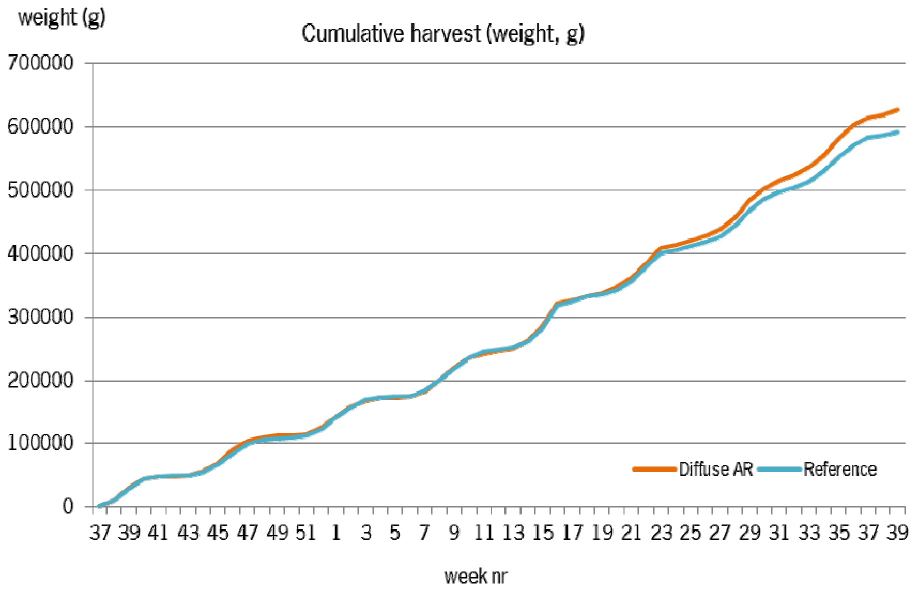

Figure 5.12. Cumulative production in gram harvested product in both compartments.

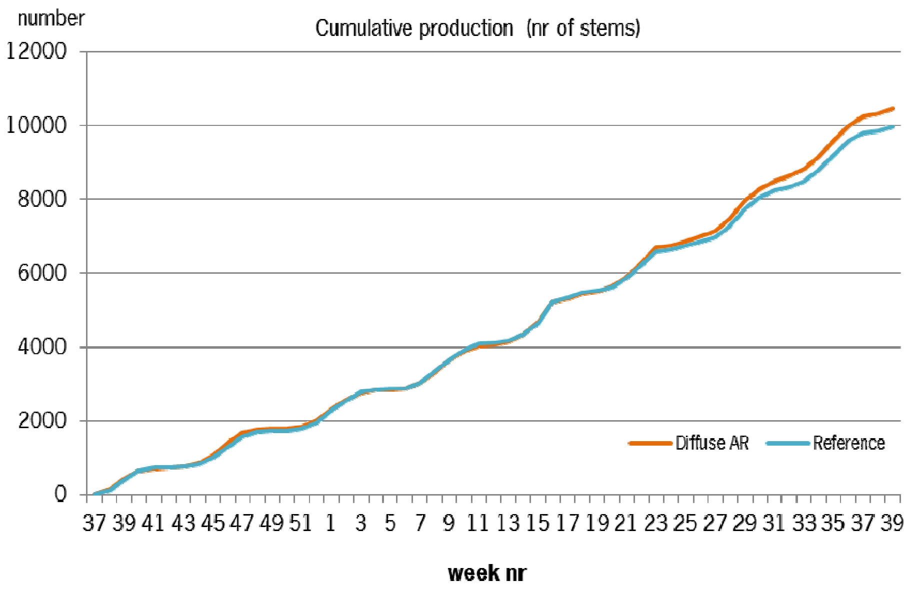

Figure 5.13. Cumulative production in number of harvested flowers (= stems) in both compartments.

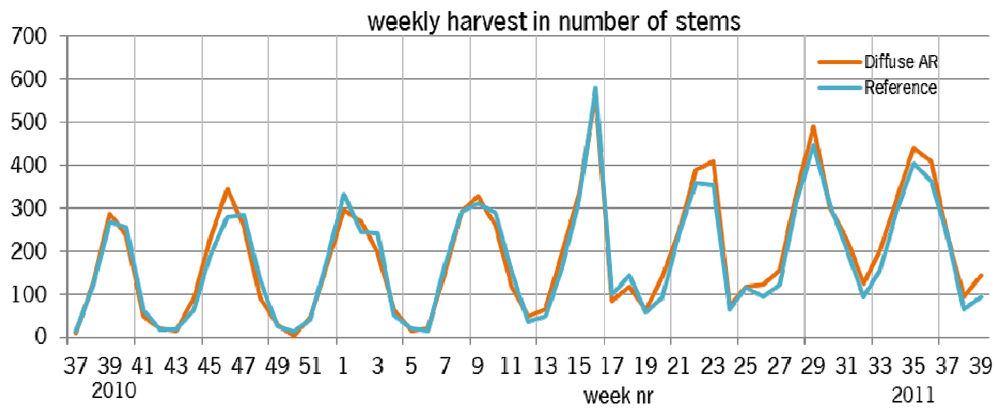

Figure 5.14. Weekly production in number of harvested flowers (= stems) in both compartments.

Because of a slightly higher average stem weight of the harvested flowers in the Diffuse AR greenhouse, see 5.3.3 , the extra stems harvested in the diffuse greenhouse represent a total production in harvested weight of 6,1% extra fresh weight production with respect to the reference glazed greenhouse.

The measurement fields include 324 plants and cover a surface of about 50 m^2.

5.3.3 Effects on flower quality

5.3.3.1 Flower length and weight

The quality of the roses is expressed with the average stem length (includes the flower), the average flower weight (includes the stem), and the average bud length (only the flower. Table 5.4 shows the average over the research period for all the harvested flowers in both greenhouses.

Table 5.4. Flower quality aspects of the roses harvested in both greenhouses

	Reference greenhouse (normal float)	Trial Greenhouse (Diffuse AR glass)
Stem length (cm)	79,1	79,3
Stem weight (g)	60,5	60,9
Bud length (cm)	4,5	4,6
Flowers with petal blueing (% of total)	6,3	7,1

The average stem quality (expressed as average length and average weight per stem) is in both greenhouses comparable to each other, as on average, the stems harvested in both greenhouses differ only 0,2 cm and 0,4 gram, and bud size differs only 0.1 cm, all in the advantage of the Diffuse AR greenhouse.

5.3.3.2 Quality remarks

Other quality remarks (see figure 5.15), such as physiological disorders (flower hearts that are not perfectly spirally turning), visible disease (such as visible powdery mildew spots on the leaves), and the blue edges on the petals decrease the market value of the roses. They have been recorded to see whether the glasshouse cover could have any influence on the incidence with which they appear.
The incidence of physiological disorders is similar in both compartments. An exception is the blue edges on the petals, that are attributed, according to grower's experience, to high radiation levels inside the greenhouse in March and April 2011,. This was the period where we experimented with the screening regimes. The percentage of flowers with petal blueing was therefore slightly higher in the Diffuse-AR coated greenhouse (see table 5.4).

Figure 5.15. Quality remarks. Left, round heart, centre, turning hearts; right, blue petal edges.

5.3.3.3 Temperature of the flower bud

The temperature of the bud did not variate much from bud to bud in both greenhouses on clouded days or with the lamps on (Maximum measured difference was 3°C from the warmest to the coldest bud in the greenhouse). However, on sunny days, the difference in temperature between the coldest and the warmest bud could reach 12-13 °C.
The part of the bud that was directly in the sun was usually hotter than on the shadow side.

An interesting difference between the flowers in both greenhouses was observed when comparing the difference between measured bud temperature and the greenhouse temperature at the moment of the measurement, see figure 5.16. On cloudy days the buds in both greenhouses are 1.0 to 1.5 degrees warmer than the air. But on sunny days from 21th of March, we see that the difference between greenhouses increases: compared to the air, the buds in the reference greenhouse are warmer than in the greenhouse with Diffuse AR coated glass. The values of April 8th show a change in this pattern: this is caused by the use of the sun screen in the reference greenhouse, but not in the Diffuse AR one.

Despite the positive effects in controlling bud temperature, the Diffuse AR glass can not avoid the blueing of the petals. Growers experience is that the petal blueing is a direct consequence of high radiation. By labelling some buds where high temperatures were measured (above 32°C), and observing whether this buds would become blue (before or several days after harvest) we could conclude that indeed high bud temperatures lead to blueing. We did not do any further research to find out which are the maximum acceptable temperatures. Instead, we looked at methods to cool down the buds other than the usual screening. Extra air movement provided by a hand ventilator producing an airstream of 1 m/sec seems effective. Depending on the blowing time, it could help to reduce the bud temperature between 0,5 and 5 degrees. This was measured by means of a hand IR meter and a thermal picture camera.

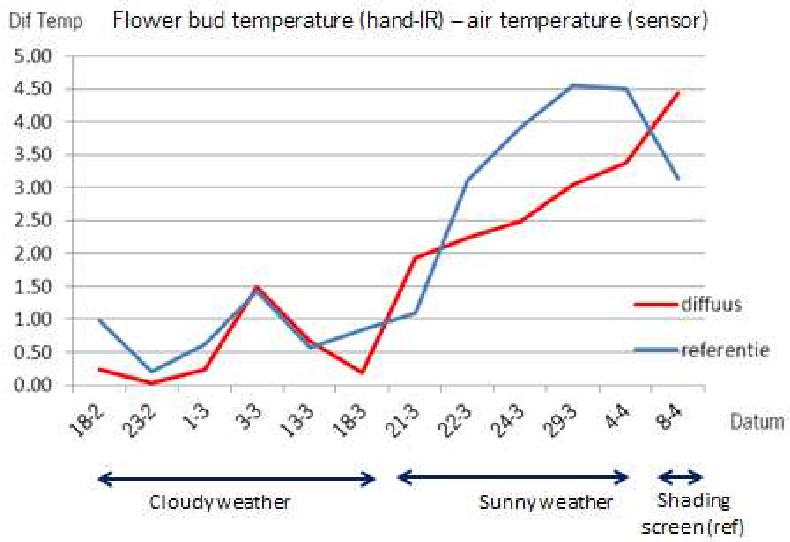

Figure 5.16. Difference between the bud temperature (measured with a hand-held IR device) and the air temperature (measured with a temperature sensor) in both greenhouses. Measurements performed February to April 2011.

5.3.3.4 Leaf tip burning

In days following high light intensities, leaf tip burning-drying was observed (figure 5.17). Young, red leaves are the most affected. Older leaves seem able to cool themselves by transpiration. With the aid of the thermal camera we could see that the leaves that burnt are the ones that heat up the most.

Figure 5.17. Leaf tip burning as consequence of high light intensity.

Simple counts of number of burnt leaf tips (figure 5.18) in each greenhouse showed that in days with high radiation, more leaf tip burning is counted in the reference greenhouse than in the greenhouse with Diffuse AR glass. The difference disappeared when the sun screens started to be used, which was the beginning of April in the reference greenhouse and half April in the Diffuse AR Greenhouse.

Figure 5.18. Number of burned leaf tips in both greenhouses, March to May 2011.

5.3.4 Effects on leaf photosynthesis

The net photosynthesis rate of plants in both compartments was comparable in all the measurements regardless of the measurement season, in other words, there were no differences found in the leaf photosynthesis of the plants grown in both compartments. Fig. 5.19 shows the results of the November measurements (as an example) for both the horizontal canopy (bent stems, older leaves and lower photosynthesis) and the vertical canopy (harvestable stems, younger leaves and higher photosynthesis). Differences within the canopy can be explained by the fact that the bent stems are often in the shadow of the vertical stems; also the age of the bent stems could influence photosynthesis as 5 weeks after bending a strong reduction in photosynthetic capacity can be observed (Schapendonk et al., 2009).
Differences were expected in the advantage of the Diffuse compartment, as in previous research with vertical vegetable crops (Hemming et al., 2008A) the plants grown in diffuse light showed a higher net photosynthesis rate. Moreover, in experiments with tomato running more or less at the same time, is has been demonstrated (Dueck et al., 2011) that in days with very high irradiation, and under the diffuse

glass (haze 71%), the photo inhibitive effect of high light intensities is considerably lower than under normal glass.
Lack of photo inhibitive conditions during our measurements (November, January and May) could explain why no differences were measured in this experiments.

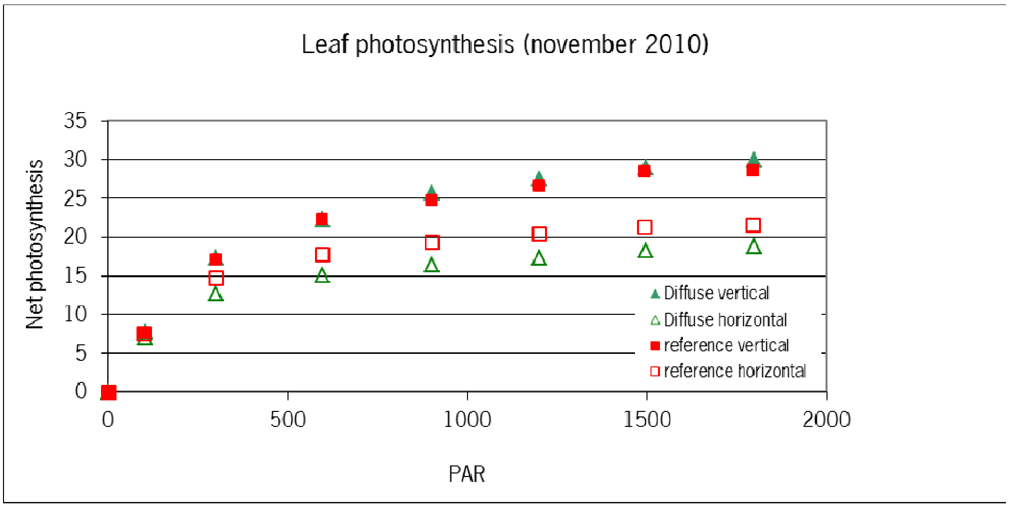

Figure 5.19 Leaf net photosynthesis in both compartments as measured in November 2010 horizontal canopy are the bent stems, vertical canopy are the harvestable stems.

5.3.5 Effects on light interception by the crop

The light interception by the crop as it was measured in January is shown in Fig. 5.20 (top); the April measurement is shown in Fig. 5.21 (down). The light intensity measured at bud level of the plant is set as 100%; the light measured at lower levels is expressed as % of the light measured at bud level. At the height of the bent canopy, very little light is received. Both curves, measured in the greenhouses with the two types of glass cover, are nearly identical, regardless of the measurement season. The different shape of the curves in both seasons is due to the flush effect in the production: the crop in January was at the end of a production flush (low LAI), while in the April situation, the production flush had just started (high LAI) and therefore very little light is reaching the lower parts of the bent canopy. However, the glass cover does not seem to influence the light interception by the crop, as it does in vertically growing crops with a height over the crop of more than 2 meters, as it is the case in tomato (Dueck et al., 2012) and in cucumber.

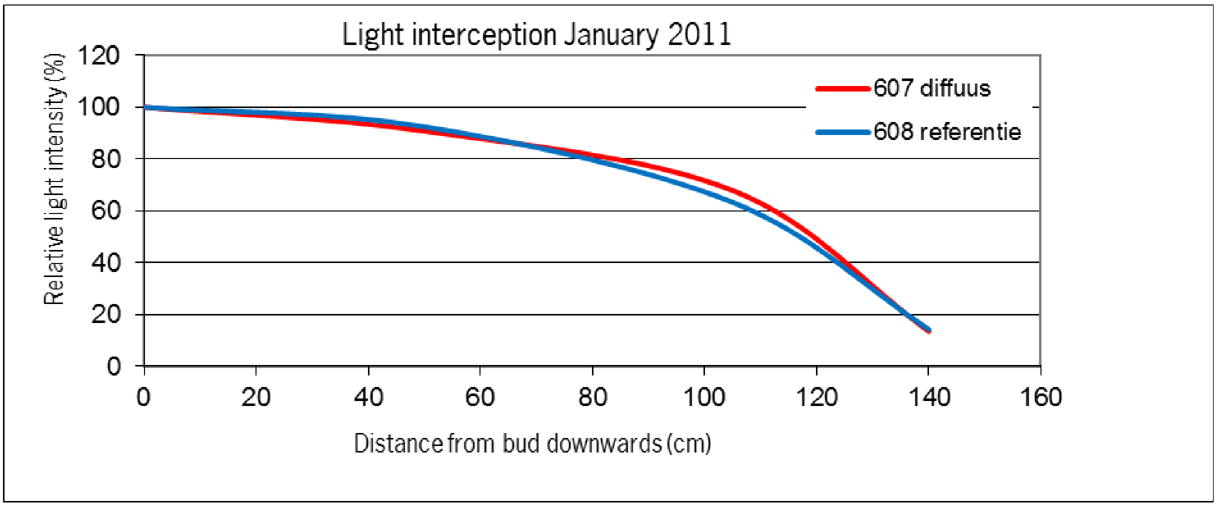

Figure 5.20. Light interception by the crop in January 2011 in both compartments.

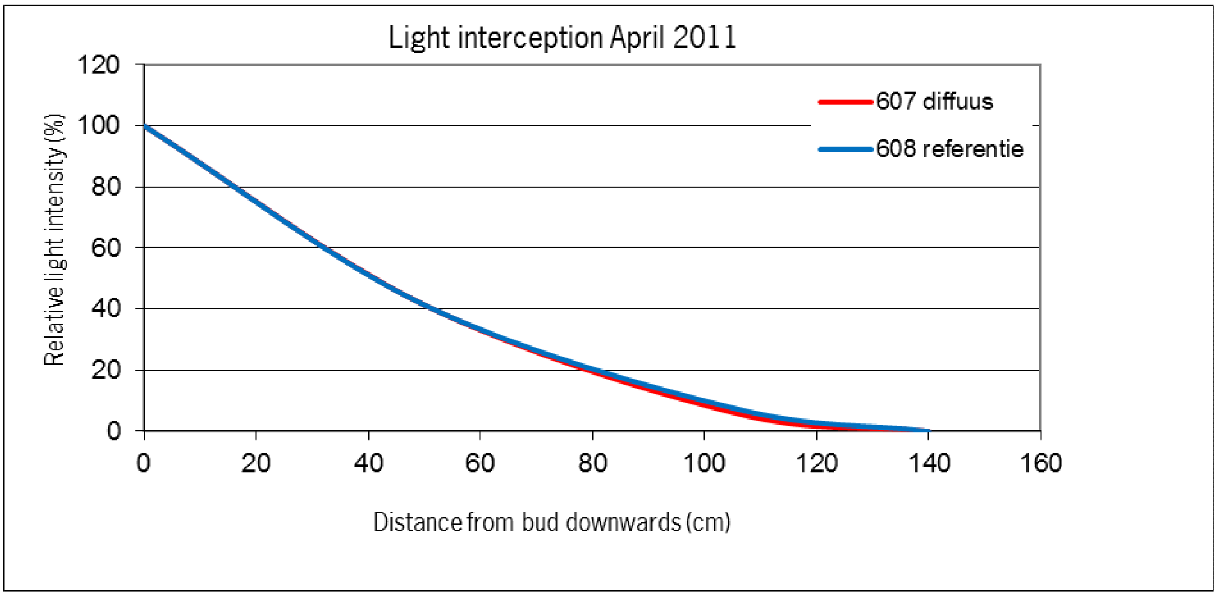

Figure 5.21. Light interception by the crop in April 2011 in both compartments.

5.3.6 Effect on vase life

The average vase life of the flowers from both compartments varied between 16.5 and 18.5 days and it is shown for the different test moments in figure 5.22. The main reason for termination of vase life in all measurements was normal wilting. Flower opening was good to very good (opening stage 4.5 to 5 in a scale from 0= tight bud to 5= fully opened flowers) at all data. There were no significant differences in vase life for flowers from both compartments.

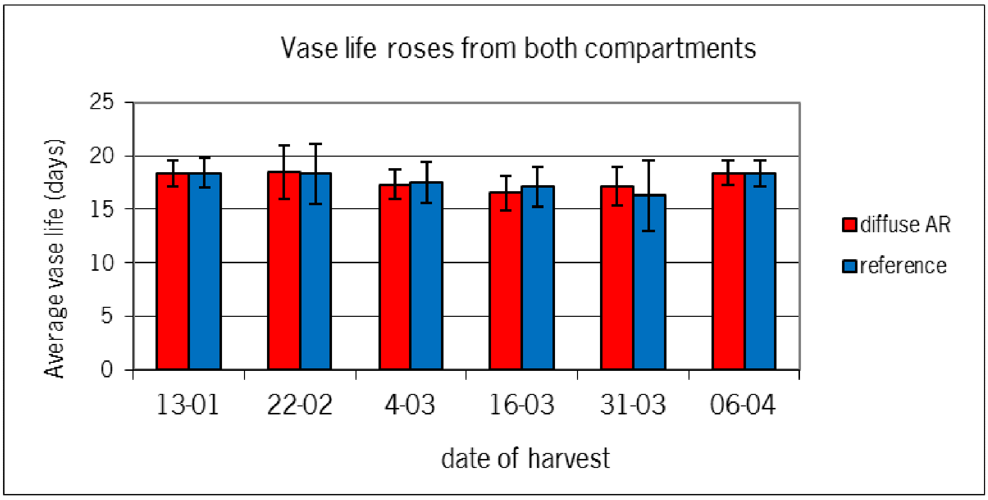

Figure 5.22. Vase life of the roses harvested at 6 different moments from plants in both compartments Y error bars indicate standard deviation.

5.4 Discussion: Perspective of AR-coated diffuse glass for rose cultivation

5.4.1 Expected versus achieved results

Diffuse Glass with AR coating on both sides of the glass lead as expected to a production increase of 5.2 % more stems and 6,1% more fresh harvest weight. This is a very nice result. However the production increase has been lower than expected when the trial started: based on results obtained with vertically growing vegetable crops (10% more fresh weight production achieved by Hemming et al., 2008A)., a 8-10% increase was expected.

This expectation was further sustained by model calculations (Schapendonk, et al., 2011) performed in the framework of another national project in the early stages of the experiment. The model forecasted a production increase of 8,5% in fresh weight for this variety, partly due to expected changes in light interception by the crop because of the diffusing properties of the light in the greenhouse, and partly because of the reduction in the need for screening. This last effect was correctly predicted by the model, although the impact on the production was lower in the experiment than in de simulation.

Moreover, in December 2010 another experiment started with diffuse glass of different Haze % with tomato (unshaded, not lighted) . The diffuse glass used had an anti-reflection (AR) coating on the outer side of the glass. The Diffuse glass lead to an important increase in production that varied proportionally with the haze factor of the glass (45%, 62% and 71%) from 8 to 11% The fruits were 5-8 g heavier, and 0.5 more trusses were formed faster under the diffuse-AR covers (Dueck et al., 2012).

The question arises, why the effect of Diffuse AR glass on rose production was lower than with vegetables, lower that expected and also lower than simulated. There are a number of possible explanations, which we discuss below: :

1- The use of screens

As explained, sun screens were necessary to protect flowers from blueing, which seems to be directly caused by overheating of the bud. During several hours a day from April to August the screen neutralizes the differences in how the light enters the greenhouse. The cop has less hours to profit from the advantages of diffuse light.

In the experiments with greenhouse vegetables no screens were used.

2- The use of artificial light.
   We have shown that the contribution of artificial light to the total amount of light in the greenhouse is high, specially in winter days it can represent more than 50% of the total light received by the crop. That leaves 50% natural light that enters through the greenhouse cover. But in the Dutch winter natural light consists by more than 50% of diffuse light. In this situation, the contribution of the cover to make light diffuse is relatively small.
   In the experiments with greenhouse vegetables no supplementary artificial light was used.

3- The rose crop is known to have a "memory". The effects of any change need some time to become apparent. In return, effects can be expected a few weeks up to 9 months. This "memory effect" might influence cumulative long term effects, that due to the short duration of the trial (one year only) we will not be able to monitor. In other words: we might have miss an effect simply because the trial was not long enough.

4- Roses are grown with a particular plant architecture. The crop does not grow high as tomatoes and cucumbers, but consists of a combination of a bent canopy that supplies the energy for the bud outgrowth and a vertical canopy that provides energy for the harvestable stems after the bud has been formed. Photo inhibition seen at the top of a tomato crop could simply not occur in roses as the (reddish) younger top leaves contribute less to the stem photosynthesis than the lower situated leaves. 5- The cultivation occurred in marked "flushes", as it can be appreciated in the week production along the year. This strong "flush" effect is a genotypic property linked to apical dominance, strongly determining production capacity, which tends to be lower for varieties with high apical dominance (Trouwborst, 2010)

This four reasons suggest that a higher increase in production could have been achieved with other rose varieties that
a) were less sensitive to leaf tip burning and petal edge blueing
b) had a genetically lower apical dominance (a flush effect in production less pronounced than the chosen cv Red Naomi!.
Such other varieties might allow a further increase of the radiance threshold for screening or even to totally avoid screening, allowing more chance for the properties of the cover to affect the crop.

5.4.2 Discussion of observed effects

The diffuse anti reflection coated greenhouse glass cover made the light incidence inside the greenhouse less erratic (with less moments of extreme high and extreme low values). Presumably this is mainly to thank to the anti-reflection coating. It is worth to emphasize (as shown in figure 5.9), that the presence of antireflection coating on just one side of the glass (the type of glass used in an adjacent greenhouse), already has a positive effect on how the light enters the greenhouse. The erraticity of the light in the greenhouse is lowest with anti reflection on both sides (the type of glass supplied by GroGlass for this experiment).

The smoother light did not result in differences in daily light sum, as the transmission of both greenhouses was very similar, but it reduced the need for screening (required to avoid leaf tip burning and blue flower edges) with 100 W/m^2 as compared to the compartment with normal float glass. It is not well understood why the blue edges appeared as a result of high irradiation values, but because buds, and young red leaves, do not have a mechanism to cool down as developed leaves do by means of transpiration, they heat up. The high bud temperature could induce pH changes in the petal tissue that cause the colour change of the anthocians (color pigments) from red to blue. If there was a method sufficiently efficient to cool down the bud temperature in the greenhouse it would reduce the need for screening further with this variety. That might enhance the effects of the diffuse glass cover.

The differences in screening regime from April on, consequence of the positive effects of the diffuse AR glass on controlling the bud temperature, lead to a difference in total light integral between both greenhouses of in total 2,7%, more in the diffuse AR greenhouse than in the reference greenhouse. If we consider the "light rule of thumb[1]" by which 1% more light = 1% more production then the extra light sum would explains roughly half of the extra production obtained.

That leaves roughly the other half of the production unexplained by the measurements performed:

- -we could not measure differences in light interception throughout the crop as a result of the glass cover properties, as measured in in high wire vegetable production (Hemming et al., 2008A, Dueck et al., 2012)
- -Leaf photosynthesis measurements did not support either an increased photosynthetic capacity of the plants grown under the diffuse glass cover.

Stanghellini et al., demonstrated in 2010 that condensation against the greenhouse cover is an important cause of a lost of light transmission inside the greenhouse. With normal float glass, this transmission loss can reach up to 5%. Condensation against a prismatic surface, as the inner side of the diffuse AR glass however, did not cause this transmission loss. It is not totally understood why, and at the time of writing this report more research is being conducted to understand this effect. Nevertheless, this unconsidered factor could provide an explanation to the other half of the extra production achieved.
Growers impression during the trial was that the fact that all the light that comes in is diffuse and less erratic makes the crop fresher, and therefore more productive. This is a non measurable explanation for the rest of the effects.

5.5 Conclusions diffuse glass in rose cultivation

The results of this greenhouse experiment with roses grown under two different greenhouse glass covers lead to the following conclusions:

1- The diffuse glass greenhouse cover with Anti Reflection coating on one side of the glass has a positive influence on the production of the rose cv Red Naomi!

2- Compared to the reference greenhouse (clear glass), the diffuse glass compartment showed an increase in production of 5,2 % more stems and 6,1 % more fresh weight.

3- The average stem length and bud length were not significantly affected by the glasshouse cover. The average stem weight was slightly higher, although not significantly, for the diffuse+ AR coating.

4- The diffuse anti reflection coated greenhouse glass cover made the light incidence inside the greenhouse less erratic, with less moments of extreme high and extreme low values.

5- The smoother light by itself did not result in differences in greenhouse temperature, in energy use or in daily light sum. However, it reduced the bud temperature increase with respect to the air temperature and lead to less leaf tip burning. These effects reduced the need for screening with 100 W/m^2 as compared to the compartment with normal float glass.

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[1] The "light rule of thumb" is a very rough indication of how light affects production, usually managed in practice by growers and advisors. However, recent research show that this "rule" is very much affected by factors as temperature, CO_2, the type of crop, the season of the year and by diffussion of the light.

6- The differences in screening regime lead to a difference in total light integral between both greenhouses that amounted 142 Mol/m^2. This represents 2,7% of the total light received by the reference greenhouse and by the in practice used “light rule of thumb” it provides an explanation for almost half of the total production improvement in the diffuse+ AR glazed greenhouse.

7- The positive effect on flower production of the diffuse glass cover cannot be explained by differences in light interception throughout the crop (as it is with high vegetable crops).

8- There was no increased photosynthetic capacity observed in the plants as a consequence of the differences in glass cover.

9- The vase life of the roses from both compartments was not influenced by the greenhouse cover.

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6 Test-site Tuscany, Italy. Results of the use of closed loop nutrient management system on tomato soilless culture

6.1 Introduction

The application of closed-loop substrate culture to greenhouse tomato cultivation was tested under the typical commercial growing conditions in Tuscany, Central Italy. The main goal was to reveal the main advantages (principally, in terms of water and fertiliser saving) of this techniques to the grower and the know-how necessary to conduct successfully the cultivation.

The test-site was set up in a commercial greenhouse farm located in Chiesina Uzzanese (Pistoia; Fig. 6.1) and consists of some plastic arch greenhouses for a total acreage of approximately 0.8 ha. Each greenhouse is 8.5 m-wide and has a gutter and maximum height of 2.30 and 4.50 m, respectively (Fig. 6.2); the area ranges from 1,000-1,500 m^2. The farm includes another array of similar greenhouses nearby (Ponte Buggianese) for a total farm surface of 1.6 Ha. The farm is currently managed by the grower with the help from his family and two employees, for a totally of 6 worker units

In terms of greenhouse structure, crop planning and management, the farm is representative of the protected horticulture in Tuscany where the diffusion of hydroponic technology is quite limited, however. Normally, tomato is cultivated from March to mid July and from late July to December.

Figure 6.1. The location of greenhouse test-site near the city of Pistoia (Tuscany, Italy).

Figure 6.2. The arch greenhouses of the Italy test site farm.

The grower (36-years old) has got a high school diploma in Agriculture and is an expert tomato grower, especially of vintage cultivars (for instance, Canestrino, see fig. 6.7) that are widely marketed in Tuscany. Since 2005 he started with the soilless culture of tomato and Zantedeschia in perlite and now has a good experience with hydroponic technology. Since 2007, tomato is the only crop planted in the farm and currently all the greenhouses are equipped with open-loop substrate culture.

Recently, the grower substituted perlite bags with Rockwool slabs. Likewise many Italian hydroponic growers, he: i) is afraid of using closed-loop fertigation irrigation due to risks of root-borne diseases; ii) knows scantily the amount of water and fertilisers supplied and lost (by drainage) in each crop cycle; iii) does not find any reason (e.g. environmental legislation, shortage of water, …) to install closed-loop growing systems. However, he accepted at once to host the trial and this suggests his interest to know more about the management of closed growing system.

6.2 Materials and methods

Two separate experiments were conducted in this farm in 2010: the first experiment was conducted in spring, from March 12th to July 21st 2010, while the second growing cycle started on 4th August on the same slabs used in spring, after removal of previous plants, and ended on 13th December 2010. For each experiment, two treatments were compared (open versus closed cycle) in two small areas of the greenhouse (60 m^2) for a total of approximately 200 stems for each treatment.

6.2.1 Plant material and cultivation method

Grafted tomato (cv. Canestrino, a vintage local tomato variety) plants were planted on March 12th 2010 (first cycle) on standard Rockwool slabs (Grotop expert) and on 4th August 2010 (second cycle) after removal of the previous cultivation. Each slabs contained three plants with two stems: crop density was of 3.6 stems/m^2. All the plants in the greenhouse were cultivated according to standard practice (in terms of pruning, pollination, pest and disease management etc.) and following the same irrigation scheduling (provided by timer). The duration of the crop cycle and the number of trusses harvested were 129 days and 5 trusses and 132 days and 4 trusses for the first and the second growing cycle respectively.

6.2.2 Fertigation

Two *ad hoc* devices (Figures 6.3 and 6.4) were built to measure the volume of the nutrient solutions fed to the crop and discharged systematically from open culture or episodically from closed culture. The nutrient solution supplied to closed system was prepared automatically by two volumetric injectors (Dosatron®). EC and pH of the nutrient solution in the mixing tank was checked manually every 2-3 days. Leaching fraction (LF) was around 20.3% in both treatments in the first cycle, while in the second experiment, it was approximately 14% and 33 in open and closed system, respectively. Five and four trusses were left on the plants in the first and second experiment.

Figure 6.3. The installation of the experimental growing systems set up in the Italy test site greenhouse.

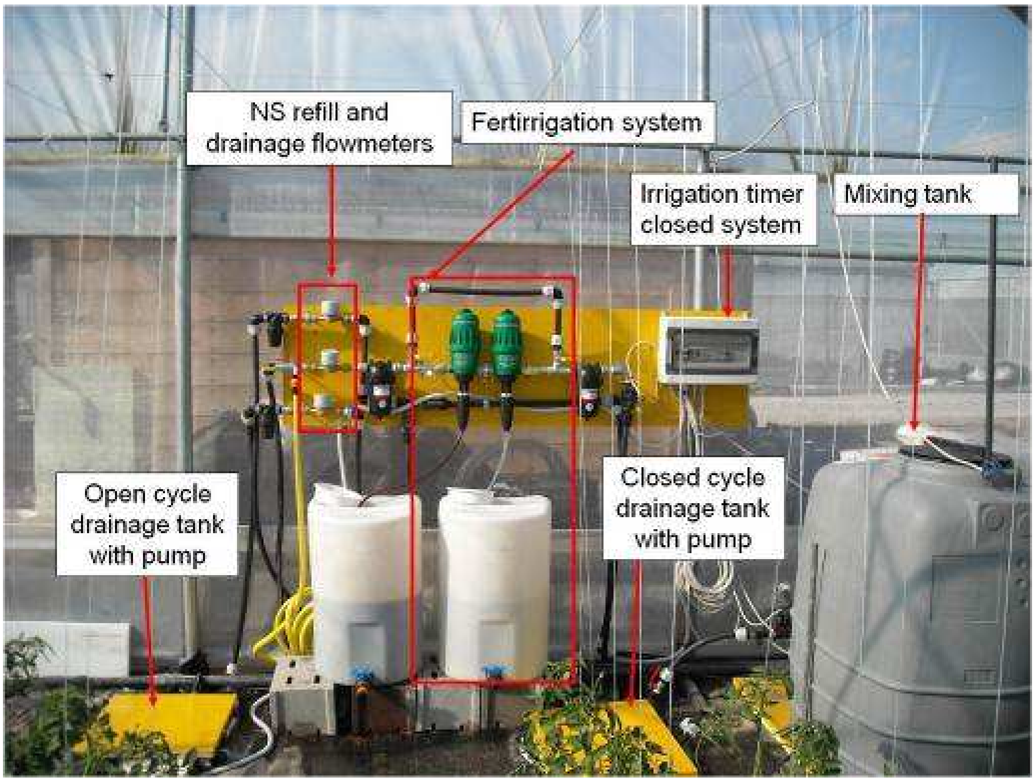

Figure 6.4. The layout of the closed soilless growing system.

Table 6.1. The average ion composition of the irrigation water and the nutrient solution fed to tomato plants grown in open or closed Rockwool culture (means of both growing cycles).

	Unit	Irrigation water	Nutrient solution (open cycle)	Refill nutrient solution (closed cycle)
EC	dS m^{-1}	0.6	2.60	2.25
pH		7.2	5.8	5.1
HCO_3	(mol m^{-3})	5.60	0.50	0.30
N-NO_3	(mol m^{-3})	-	12.10	10.30
N-NH_4	(mol m^{-3})	-	0.70	0.52
P	(mol m^{-3})	-	1.10	1.10
K	(mol m^{-3})	-	7.40	7.20
Ca	(mol m^{-3})	1.70	5.40	4.32
Mg	(mol m^{-3})	0.60	1.97	1.40
Na	(mol m^{-3})	2.60	2.52	2.52
Cl	(mol m^{-3})	1.20	1.99	1.20
S-SO_4	(mol m^{-3})	0.10	4.63	3.66
Fe	(mmol m^{-3})	1.7	14.6	16.0
B	(mmol m^{-3})	0.1	31.3	25.4
Cu	(mmol m^{-3})	0.3	1.30	1.1
Zn	(mmol m^{-3})	1.3	7.2	4.3
Mn	(mmol m^{-3})	6.2	7.0	10.0

In open system, the crop was fertigated according to the grower's protocol, which was designed by his consultant (from Grodan company). In closed system, the plants were fed with a slightly different nutrient solution (in general with lower concentration) respect to the one used by the grower, with the aim to maintain quite constant the concentration of the nutrients in the recirculating nutrient solution (see Tab. 6.1 for the average nutrient solution applied in the open and closed system). These modifications were necessary due to the high concentration of calcium and magnesium (as bicarbonates) in the raw water. Table 6.1 reports the average ion concentration of irrigation water and the nutrient solution used in open or closed system.

In closed system, recirculating nutrient solution was periodically (roughly, every one or two weeks) sampled and analysed with a reflectometer in order to adjust the composition of the refill nutrient solution. It was also planned to discharge partially the recirculating nutrient solution (about 60% of the total volume, equal to 6.7 L m^{-2}, as expressed per unit ground area) to whenever EC exceeded 4.5 dS m^{-1} and N-NO_3 concentration dropped below 1.0 mol m^{-3}. This value was selected because 20 mg L^{-1} (1.42 mol m^{-3}) is the limit imposed to the NO_3^- concentration of wastewater discharged into surface water by the current Italian legislation associated with the implementation of European Nitrate Directive. It was planned to discharge the recirculating nutrient solution from closed system when both conditions would have been fulfilled: i) EC >4.5 dS m^{-1}; ii) [N-NO_3^-] <1.0 mol m^{-3}.

6.2.3 Data collection

In both growing systems, the following data were collected or computed: i) volume, EC and ion concentration of supply and drainage nutrient solutions; ii) fruit yield and quality; iii) water and nutrient balance. Fruit quality was evaluated by measuring firmness, pH, EC, total soluble solids (TSS), titrable acidity and dry matter content in marketable berried picked from second and fourth trusses Every week the nutrient solution retained by the slabs was collected with a syringe soon after an irrigation (generally, in the morning) and checked for EC.

Data were analysed by ANOVA and mean values were separated using LSD test.

6.3 Results

Due to the low NaCl concentration in the raw water, in closed system the nutrient solution was never discharged.

In both seasons, there were no important differences between closed and open system in terms of EC and Na concentration in the nutrient solution supplied to the plant (on average 2.58 dS m^{-1} and 3.41 mM, respectively), drained out from the slabs (2.73 dS m^{-1} and 4.71 mM, respectively) or contained in the substrate (3.41 dS m^{-1}; Na content was not determined).

No significant differences were found between open and closed culture in terms of crop evapotranspiration: the cumulative water uptake for both experiments was around 6950 and 6831 m^3 ha^{-1} for open and closed system, respectively (Table 4.2). The cumulated value of crop evapotranspiration and the EC of irrigation water for the first growing cycle (data from 15th April till 21th July 2010), are reported in fig 6.5 and 6.6.

Balance sheets for water, N, P and K are shown in Table 4.2. The application of closed system reduced significantly the use of water (-21%) and nutrients (-17 to -35%) and made it possible to carry out the cultivation without any nutrient leaching, which instead was massive in open culture (Table 4.2).

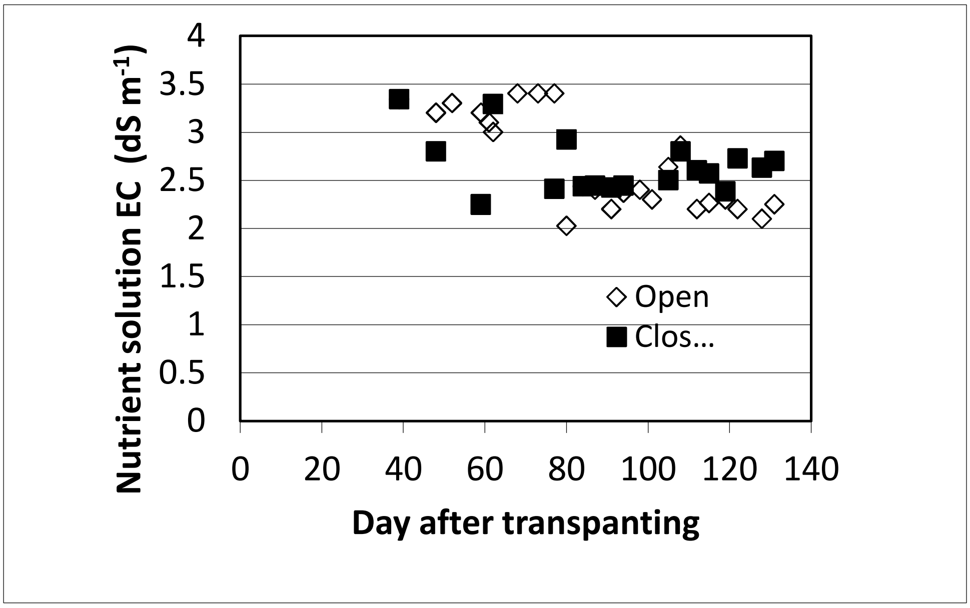

Figure 6.5. The EC of the nutrient solution supplied to open culture or recirculating in closed loop tomato culture during the first growing cycle (15th April-21 July 2011).

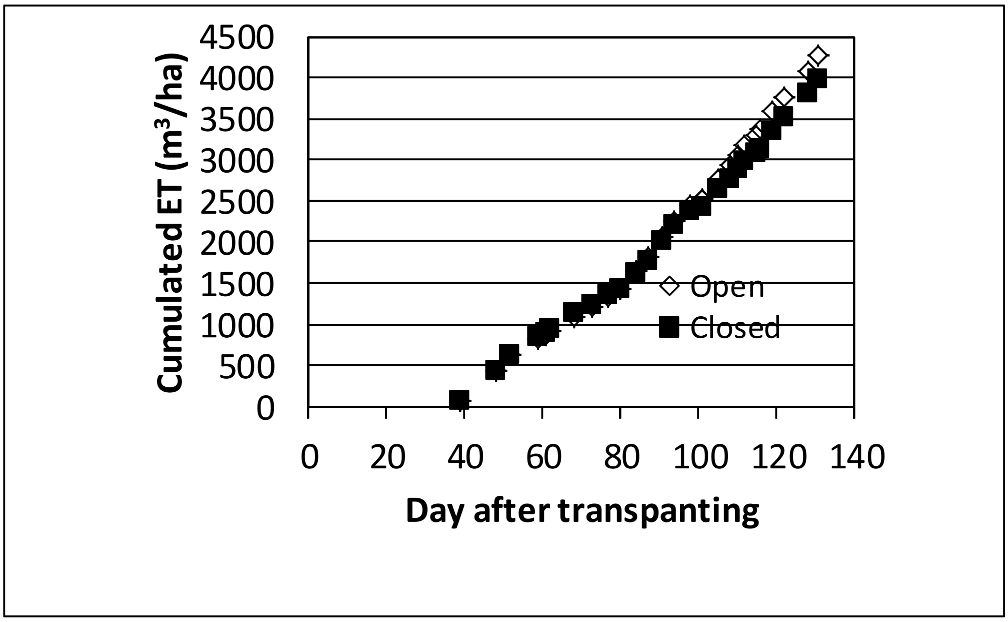

Figure 6.6. Cumulated tomato evapotranspiration recorded in open or closed loop tomato culture during the first cycle growing cycle (15th April-21 July 2011).

The total and the commercial yield harvested were 21.5 and 19.9, respectively, in open culture against 20.1 and 19.6 kg m^{-2} in closed culture; these differences were not significant. Mean weight of marketable berries was 149.6 and 153,3. g in closed and open system, respectively (also not significant). Growing system did not affect significantly most quality attributes determined in marketable berries (see table 6.3) apart from dry residue and TSS in the first growing cycle, which were respectively 5.5% and 4.5 °Brix in open culture, and 6.3% and 5.0°Brix in closed culture.

Table 6.2. Water and nutrient balance sheets for closed and open culture of greenhouse tomato (cumulated values of both growing cycles). The value of uptake included the amount of water or nutrients remaining in the substrate at the end of growing season.

Parameter	Unit	Open system	Closed system	Difference
Water use	m^3 ha^{-1}	8631.6 a	6831.1 b	20.9%
Drainage water (run-off)	m^3 ha^{-1}	1682.0 a	0 b	100.0%
Water uptake	m^3 ha^{-1}	6949,6 a	6831.1 a	1.7%
Supply N	kg ha^{-1}	1597.7 a	1032.4 b	35.4%
N leaching	kg ha^{-1}	266.5. a	0 b	100.0%
N uptake	kg ha^{-1}	1331.2 a	1032.4 b	22.4%
Supply P	kg ha^{-1}	306.7 a	244.0 b	20.4%
P leaching	kg ha^{-1}	25.3 a	0 b	100.0%
P uptake	kg ha^{-1}	281.4 a	244.0 b	13.3%
Supply K	kg ha^{-1}	2422.1 a	2000.7 b	17.4%
K leaching	kg ha^{-1}	343.5 a	0 b	100.0%
K uptake	kg ha^{-1}	2078.6 a	2000.7 b	3.7%

Table 6.3. Influence of open and closed growing system on the yield and fruit quality of tomato crop in the Italy test site. For the quality parameters, the average values between second and forth trusses were been reported. For each cycle and parameter, a different letter denotes a significative difference according the LSD test ($P<0.05$).

Parameter	First cycle		Second cycle		Total	
	Open	Closed cycle	Open	Closed cycle	Open	Closed cycle
Total yield (kg m^{-2})	14.90 a	14.40 a	6.60 a	6.40 a	21.50 a	20.80 a
Total commercial yield (kg m^{-2})	13.90 a	13.70 a	5.90 a	5.90 a	19.80 a	19.60 a
N° commercial fruits (n°fruits m^{-2})	97.3 a	101.0 a	33.1 a	32.4 a	130.40a	133.46 a
Fruit size (g $fruit^{-1}$)	143.0 a	135.3 a	179.6a	183.a	152.3 a	146.9 a
Not commercial yield	1.05 a	0.70 b	0.70 a	0.5 a	1.75 a	1.20 b
Firmness (kg m^{-2})	5.66 a	5.11 a	5.83 b	6.30 a	5.74 a	5.70 a
Dry matter content (%)	5.53 b	6.27 a	4.43 a	4.54 a	4.98 b	5.41 a
Total Soluble Solids (°Brix)	4.51 b	5.00 a	3.58 a	3.65 a	4.04 b	4.33 a
Titratable acidity (% citric acid)	0.40 a	0.44 a	0.35 a	0.35 a	0.37 a	0.40 a
Fruit juice pH	4.60 a	4.61 a	4.55 a	4.54 a	4.57 a	4.58 a

Figure 6.7. Canestrino tomatoes grown in the greenhouse farm in Chiesina Uzzanese (Pistoia, Italy).

6.4 Conclusions closed loop fertigation

As expected, closed system increased water and nutrient use efficiency and minimize environmental impact with minor effect of fruit yield and quality. The grower appreciated the positive implications of closed growing system, in particular the reduction of fertilisation costs. Indeed, one of the grower goals for the next future is to optimize the fertigation regime in order to reduce the use of soluble fertilisers, which actually is quite large due to the high nutrient concentration of the fertigation water and not as result of over-irrigation (leaching fraction was relatively low). However, the grower is still afraid of the occurrence of root-borne diseases and the application of closed growing technology is not foreseen for the near future.

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7 Economic and environmental impact of some of the Implemented developments

The economic and environmental implications of two of the developments tested (diffuse glass with AR coating in rose; reduced Rockwool volume in rose cultivation, both in the Dutch situation) have been evaluated within WP 1. This evaluations are an integral part of the Deliverables 5 and 13 of the EUPHOROS project (Ruijs, M.N.A., Montero J.I., Anton, A., Torrellas, M., 2009 and 2011). A small extraction of the results is shown in 7.1 and 7.2.

The economic feasibility of the use of a closed loop fertigation system in the Italian situation was evaluated; because of the location change for this development (Italy instead of Hungary), this evaluation was not performed within WP1, but within WP6 by Marc Ruijs (Wageningen UR Greenhouse Horticulture), fed by data collected by UNIPI. The economical convenience was evaluated computing the pay-back time of the investment, calculated as the ratio between the investment cost and the annual net saving (fertilisers and water saved costs minus the major variable costs). The reduction of the fertiliser cost was computed on the basis of the yearly average nutrient solution cost adopted by the grower multiplied for the yearly total water use for both options. The results of this evaluation are integrally shown in 7.3

7.1 Diffuse glass with AR coating

With the obtained increase in flower yield of 5.2 % more stems of equal to slightly better quality, the examined glass (tempered, by GroGlass double-sided AR coated Vetrasol 503) can be economically feasible (Ruijs et al., 2011), as it has been calculated that 1,5 % more production already can finance the extra investment costs necessary for this type of glass with a payback period of 4 year (Calculations based on price estimates by one supplier).

Despite the fact that for the production of the Diffuse glass with AR coating requires extra electricity, the environmental analysis (Torellas et al, 2011) has shown that with the obtained yield increase (it was calculated with 5%) the development had an obvious benefit reducing environmental impacts of the production system. In terms of environmental impact this increase in yield compensated the extra energy required for the production of diffuse glass compared to standard glass. Environmental impacts were reduced around 4.6% to all considered impact categories.

7.2 Rockwool plugs and smaller slabs

The rose plants (Rosa hybrida cultivar 'Red Naomi!') for the diffuse AR glass greenhouse cover trial in Bleiswijk were propagated by cuttings using the Synchronization Method (Van Telgen et al., 2003) of Wageningen UR Glasshouse Horticulture in Rockwool plugs (Grodan). Once the plantlets were rooted they were planted in SPU (single production units) Rockwool blocks (Grodan) of 24x20x7,5 cm with 2 plants per block (Figure 7.1, left). The reference situation (normal commercial practice, figure 7.1, right) consists of +/- 4 Rockwool blocks for propagation which are placed at planting on top of the substrate slab (100x12x7,5 cm) with Rockwool (Grodan). The used system saves 20% substrate compared to the reference.

The reduced size of the units allowed also extended propagation of the plants and transport of the productive plants (figure 12) to the experimental compartments, instead of planting small plants directly on the slab.

Figure 7.1 Left, rose plants after planting in Grodan SPU; right, reference situation (traditional)

The economic evaluation (Ruijs et al., 2011) showed that the reduction of substrate volume with SPU results in a saving of 0,10-0,16 €/m^2 depending on the SPU option. A sensitivity analysis of the substrate price points out that the savings (difference in yearly costs between the option and the standard cultivation system) are not very much affected, because of the four year cultivation period.

The environmental impact analysis (Montero et al., 2011) confirms that lower use of substrate volume produced significant reductions in auxiliary equipment (20.6% in cumulative energy demand) but had a small effect in the total production system (4.8%). This kind of results would make difficult to convince growers to implement an alternative that gives little environmental improvements in the production system and on the other hand requires extra effort in agricultural practices. However, substrate volume reduction must be equally encouraged to move to more environmental friendly practices.

7.3 Closed loop fertigation system

The economical analysis of the convenience to adopt the closed loop system for the Italian grower where the trial exposed in Chapter 6 took place is shown in table 7.1

In this particular case, due to the low leaching fraction used by the grower in the open system (21%) the adoption of closed system is not economically convenient for the grower. The convenience to use this option started with an LF higher than 26.3%.

Nevertheless, three aspects that can change the balance from slightly negative to positive, have not been considered in this analysis as they are not easy to quantify in the Italian situation:

1- the benefit of a reduction of environmental pollution
2- the cost for the environment protection.
3- The water saving when water availability is limited, like in summer or in periods of draught

Table 7.1. Investment costs, variable costs and payback time for a closed loop fertigation system in Italy.

Investment costs			
	Cost (€)	**Duration (years)**	**Annual cost (€)**
Investments cost			
UV filtration system	17500	6.7	2612
Rough sand filter and additional hydraulic components	5000	10	500
REFLECTOQUANT Merk (Portable spectrophotometer for quick chemical tests)	800	5	160
Total investment	**23300**		**3272**
Additional variable costs			
Additional variable costs	**Cost (€)**	**Amount**	**Annual cost (€)**
Lab chemical analysis	80	2	160
Reagents for quick analysis	50	1	50
DNA SCAN (Phytopathological analysis)	300	2	600
Maintenance costs (5% of investment)	1165	1	1165
Interest costs (2,5% of investment)	583	1	583
Total major variable costs			**2558**
Total annual cost			**5829**
Saving			
	m^3 ha^{-1}	**€ m^{-3}**	**€ ha^{-1} $year^{-1}$**
Closed system : average annual nutrient solution cost	6831.1	1.48	10110
Open system: average annual nutrient solution cost	8631.6	1.71	14760
Fertigation cost difference (€ ha^{-1})			**4650**
Saving (€ ha^{-1})			**-1179**
Pay-back Time (investment cost/(fertirrigation saving -variable costs)			**8.71**

After the economic analysis (see table 7.1), it could be concluded that for this Italian grower there is no economical advantage when the closed system is adopted (major net cost of 0.12 € m^{-2}). Main burden is the fact that the grower has good quality irrigation water (low sodium content), that allowed the grower to irrigate with a low LF respect to the LF threshold for the convenience (20.9% against the threshold of 26.7%).

8 Dissemination of results beyond involved stakeholders

The results obtained in the three test locations have been regularly discussed with the stakeholders involved. Beyond them, however, efforts have been done by the researchers involved in the implementation trials to disseminate the results as much as possible. Per test location, an overview is given of publications, workshops and courses used to spread the developed knowledge.

8.1 Location Almeria

8.1.1 Publications

López , J.C.; Baeza, E.J.; Montero, J.I.. 2012. New developments in plastics cladding materials for greenhouses. *In: Efficient use of inputs in protected horticulture.* - I.S.B.N.: 978-84-938787-1-9

López , J.C.; Baeza, E.J.; Montero, J.I.. 2012. Nuevos desarrollos en plásticos de cubierta para invernaderos. *In: Uso Eficiente de Inputs en la Horticultura Protegida.* - I.S.B.N.: 978-84-938787-0-2

Torrellas, M.; Antón, A.; Baeza, E.; López, J.C.; Pérez Parra, J.; Ruijs, M.N.A.; Garcia Victoria, N.; Montero, J.I. (2011) Three European protected crops: LCA and alternatives to reduce environmental impact Montpellier, France : International conference on Environmental & Integrated assessment of Complex Systems Conference, 2011-11-30/ 2011-12-02

White, S.; Clarkson, J.; Napier, R.; Bálint, Á.; Garcia Victoria, N.; Incrocci, L.; Romero, E.J.B.; Skirvin, D. (2011) Implications of sustainable greenhouse systems for pest and disease (ET 5)
Halkidiki, Gr. : Oral presentation GreenSys2011, 2011-06-07

White, S.D., 2012. Implications of new sustainable greenhouse systems for pests, diseases and biological control: A modelling approach using *Oidium neolycopersici* and *Tetranychus urticae*". Phd Thesis. Warwick University, UK. (in press).

8.1.2 Workshops and courses

Almeria, (Spain). Advanced course on “Efficient use of inputs in protected horticulture, Almeria, Spain, 8 February 2012. (Participants, 25 people). Desarrollos del proyecto para invernaderos de cristal con cultivo de rosas. Garcia Victoria, N. (2012)

Almeria, (Spain). Seminar on “Efficient use of inputs in protected horticulture, Almeria, Spain, 9 February 2012. (Participants, 200 people).

8.2 Location Bleiswijk

8.2.1 Publications

Garcia Victoria, N. (2012). Desarrollos del proyecto para invernaderos de cristal con cultivo de rosas *In: Uso Eficiente de Inputs en la Horticultura Protegida.* - I.S.B.N.: 978-84-938787-0-2

Garcia Victoria, N. (2012) Euphoros developments applicable for rose cultivation (The Netherlands) *In: Efficient use of inputs in protected horticulture.* - I.S.B.N.: 978-84-938787-1-9

Vegter, B.; Petter, M.; Sleegers, J.; Dueck, T.A.; Garcia Victoria, N.; Ruijs, M.N.A. (2012) lichtverstrooing: vooral voordelen (interview met Tom Dueck en Nieves García)
Vakblad voor de Bloemisterij 67 (4). - p. 26 - 27.

Garcia Victoria, N. (2011) Veel rustiger licht onder diffuus glas
Roos.actueel / Uitg. van de landelijke Cie Roos van LTO Groeiservice 14 (2). - p. 2.

Garcia Victoria, N.; Dueck, T.A.; Bruins, M.A.; Weel, P.A. van; Kempkes, F.L.K.; Stanghellini, C. (2011) Effect on rose production and quality of a diffuse glass greenhouse cover (P 27) Halkidiki, Greece : Wageningen Greenhouse Horticulture, Poster Presentation at GreenSys2011, 2011-06-06

Garcia Victoria, N. (2011) Rozen: baat bij diffuus glas : Interview met Nieves Garcia
Nieuwe oogst / LTO Noord. Editie Noord 7 (45). - p. 25.

Garcia Victoria, N. (2011) More regular light for rose under diffuse glass
Wageningen : Wageningen UR, , 2011-05-24

Garcia Victoria, N. (2011) Spannende periode bij diffuus glas roos Energiek2020 : Energiek2020.nl, , 2011-02-07

Garcia Victoria, N. (2011) Diffuses Glas: Erhöht Rosenproduktion um 5% Gabot.de, , 2011-11-08

Garcia Victoria, N. (2011) Veel rustiger licht bij roos onder diffuus glas
Wageningen UR Glastuinbouw, , 2011-05-20

Garcia Victoria, N. (2011) Effecten diffuus glas kasdek in onderzoek
Roos.actueel / Uitg. van de landelijke Cie Roos van LTO Groeiservice 14 (1). - p. 3.

Torrellas, M.; Antón, A.; Baeza, E.; López, J.C.; Pérez Parra, J.; Ruijs, M.N.A.; Garcia Victoria, N.; Montero, J.I. (2011) Three European protected crops: LCA and alternatives to reduce environmental impact Montpellier, France : International conference on Environmental & Integrated assessment of Complex Systems Conference, 2011-11-30/ 2011-12-02

White, S.; Clarkson, J.; Napier, R.; Bálint, Á.; Garcia Victoria, N.; Incrocci, L.; Romero, E.J.B.; Skirvin, D. (2011) Implications of sustainable greenhouse systems for pest and disease (ET 5)
Halkidiki, Gr. : Oral presentation GreenSys2011, 2011-06-07

Garcia Victoria, N. (2011) Roos onder diffuus glas ruim 5% meer productie
Energiek2020 : www.Energiek2020.nl, , 2011-11—01

Garcia Victoria, N. (2011) Ruim 5% meer productie bij rozenteelt onder diffuus glas
Agriholland nieuws. www.agriholland.nl, 2011-11-01

Garcia Victoria, N. (2011). 5 procent meer productie roos onder diffuus glas. Niews article, Vakblad voor de Bloemisterij, digital edition 4 November.

García Victoria, N. ; Kempkes, F.L.K., Van Weel, P. ; Stanghellini, C.; Dueck, T. and Bruins M. (2011) Effect of a Diffuse Glass Greenhouse Cover on Rose Production and Quality. Acta Horticulturae, (in press).

Kempkes, F.L.K., C. Stanghellini, N. García Victoria, M. Bruins. 2011. Effect of diffuse glass on climate and plant environment: first results from an experiment on roses. Acta Hort. (in press)

García Victoria, N. ; Kempkes, F.L.K., Van Weel, P. ; Stanghellini, C.; Dueck, T. and Bruins M. (2011). Effect of AR coated, diffuse greenhouse glass cover on rose production and quality. Poster presentation during the “Tecnical Trials Tour” of the Hortifair, The Netherlands, October 2011. See as APPENDIX-3.

García Victoria, N. (2011). Effect van diffuus kasdek met Anti Reflectiecoating bij Roos. Wageningen UR Glastuinbouw, Rapportnummer GTB-1128 (in press)

Anonimous (2010). Onderzoek naar diffuus glas in rozenteelt.. Niews article, Vakblad voor de Bloemisterij, digital edition 22 July.

Garcia Victoria, N. (2010) Effecten diffuus glas kasdek bij roos in onderzoek
Gewasnieuws Potplanten - bloeiende planten 13 (4). - p. 6.

Garcia Victoria, N. (2010) Effecten diffuus glas kasdek bij roos in onderzoek
Gewasnieuws Potplanten - groene en bonte planten 13 (4). - p. 6.

Garcia Victoria, N. (2010) Effecten diffuus glas kasdek bij roos in onderzoek
Potplanten Actueel. editie Seizoen / Uitg. van LTO Groeiservice 13 (4). - p. 6.

8.2.2 Workshops and courses

Bleiswijk, (The Netherlands). Workshop “The E-nose”, a diagnostic tool? Presentations by Warwick students Fraser Smith, Tharindra Kulasinghe and Daniel Sully, March 11, 2010. (12 participants).

Bleiswijk, (The Netherlands). Workshop “The E-nose”, results of first practice measurements. Presentations by Warwick Professor Dr. Daciana Ilescu. March 11, 2010. (10 participants).

Bleiswijk, (The Netherlands). Energiek Event, 2011. Worshop financed by the program “Greenhouse as Energy Source” from PT / EL&I. Presentations by Hemming, S. et al. About natural light and visit to the Rose Diffuse Glass trial. March 2011.

Almeria, (Spain). Advanced course on “Efficient use of inputs in protected horticulture, Almeria, Spain, 8 February 2012. (Participants, 20 people). Desarrollos del proyecto para invernaderos de cristal con cultivo de rosas. Garcia Victoria, N. (2012) (20 participants)

Bleiswijk, (The Netherlands). Workshop on “‘diffuus licht een helder verhaal!’ Financed by the program “Greenhouse as Energy Source” from PT / EL&I, Marcelis, L., Dueck, T., et al.. (30 participants).

Bleiswijk, (The Netherlands). Guided visits during “Technical trials tour” during International Horticulture Exhibition Hortifair. October 2012. (40 participants)

8.3 Location Tuscany

The knowledge gathered by the trial has been spread through many publications in scientific and divulgative magazines, as well as through participation in advanced courses organized in different Region of Italy and abroad:

8.3.1 Publications

Incrocci, L., 2011. Software per l’ottimizzazione della fertirrigazione delle colture fuori suolo- *Hydrotool: A Decision Support System to optimise fertigation management in greenhouse crops*.

Pardossi, A., Incrocci, L., 2012. Closed system for soilless culture. Proceeding of the Course "Efficient use of inputs in protected horticulture". Almeria, Spain, 8 February 2012. *In English/Spanish.*

Incrocci, L., Pardossi, A., Voogt, W., 2012. Analizzare l'estratto acquoso per fertirrigare al meglio. L'Informatore Agrario 16, 40-43 (In Italian).

Diara, C., Incrocci, L., Pardossi, A., Minuto, A., 2012. Reusing greenhouse growing media. Acta Horticulturae, *in press*.\

Carmassi, G., Romani, M., Diara, C., Massa, D., Maggini, R., Incrocci L., Pardossi, A., 2012. Response to NaCl salinity and excess boron in greenhouse tomato grown in 2 semi-closed substrate culture in a Mediterranean climate. Journal Plant Nutrition, *in press*.

Incrocci, L., Pardossi, A., Voogt, W., 2012. Analizzare l'estratto acquoso per fertirrigare al meglio. L'Informatore Agrario 16, 40-43.

Diara, C., Incrocci, L., Pardossi, A., Minuto, A., 2012. Reusing greenhouse growing media. Acta Horticulturae, *in press*.

Incrocci, L., Carmassi, G, Massa, D., Romani, M., Pardossi A., Campiotti, C.A., 2012. Interactive effects of boron and salinity on greenhouse tomato grown in closed soilless system. Acta Horticulturae, *in press*.

Incrocci, L., Massa, D., Pardossi, A., Bacci, L., Battista, P., Rapi, B., Romani, M., 2012. A decision support system to optimise fertigation management in greenhouse crops. Acta Horticulturae*, in press*.

Carmassi, G., Incrocci, L., Pardossi, A., 2012. EUPHOROS: un progetto europeo per la riduzione dell'impatto ambientale delle coltivazioni in serra. Colture Protette *(Submitted*).

8.3.2 Workshops and courses

Pistoia, (Tuscany): Advanced course on "Soilless cultures" Pistoia, Italy, 7-10 November 2011. (Participants, 15 people).

San Remo, (Liguria), Advanced course on "Closed system for greenhouse crops". 7-8, September 2010. (Participants: 18 people).

Szentes, (HU). Fertigation management in greenhouse hydroponics. Euphoros Workshop, 28 June 2011. (Participants, 60 people).

Pontinia, Latina, (Lazio): Advanced course on "Nutrition and growing techniques of greenhouse crops". Pontinia, (Latina, Italy), 18 marzo 2010. (17 participants).

Vittoria (Sicily): Advanced course on "Nutrition, plant protection of soilless cultures", organized by SIAD, a private company operating in the field of fertilizers, soil disinfection and soilless crop specialties 10 May 2011 (*25 participants)*.

Padova (Padova). Congress on "*Energy requirement and production on greenhouse system"*. FLORMART, 16 September 2011. (*70 participants)*

Donnalucata (Sicily): Strategies for reducing the environmental impact of soilless culture. Workshop on: "Results of the EU Project Euphoros- Efficient Use of inputs in Protected HORticulture". Donnalucata, 6 October 2011. (53 Participants).

Comiso (Sicily). Advanced course on “Climate Control in Greenhouse”. Comiso, 14 and 26 November 2011. (Participants, 30 people).

Pisa (Tuscany). Advanced course organized by VALAGRO, a private company operating on the field of fertilizers and crop specialties. 28 January 2012. (Participants, 20 people).

Almeria, (Spain). Advanced course on “Efficient use of inputs in protected horticulture, Almeria, Spain, 8 February 2012. (Participants, 25 people).

Almeria, (Spain). Seminar on “Efficient use of inputs in protected horticulture, Almeria, Spain, 9 February 2012. (Participants, 200 people).

Cesena, (Emila-Romagna). Congress on “ORTOMAC: innovazioni per una orticoltura di qualità-ORTOMAC: new technologies for a high quality vegetable crop production”. Cesena, Italy, 20 April 2012 (Participants, 30 people).

Bleiswijk (The Netherlands). Covered crops in Italy. International Workshop on Covered Crops- PPP risk assessment and management of emissions. 26-27 April, 2012, (Participants 60 people).

Appendix 1.

Invitation and program to workshop at the EEFC in june 2011.

Appendix 2.

Invitation and program to specialised course at the EEFC in January 2012.

El proyecto EUPHOROS, acrónimo de Efficent Use of Inputs In Protected Horticulture (Uso Eficiente de Inputs en Horticultura Protegida) ha recibido financiación de la UE en su 7º Programa Marco y cuenta entre sus impulsores con Universidades, Centros de Investigación y Empresas de reconocido prestigio que en Europa desarrollan su actividad en el ámbito de la I+D+i en Horticultura Protegida.

Este proyecto pretende desarrollar un sistema productivo para la agricultura en invernadero que sea sostenible, en el que se elimine la necesidad de energía fósil y la emisión al medio de agua y fertilizantes, se minimice la huella del carbono, se reciclen los sustratos utilizados y se reduzca al mínimo el uso de productos fitosanitarios, manteniendo alta productividad y eficiencia en el uso de recursos.

El contenido del curso incluye los desarrollos más relevantes alcanzados en las áreas de trabajo abordadas en el proyecto: evaluación económica y ambiental del sistema invernadero; eficiencia en el uso de la energía; ciclos cerrados en el uso del agua, fertilizantes y sustratos; reducción en el uso de fitosanitarios e integración y evaluación de las distintas herramientas desarrolladas. Las clases serán impartidas por los investigadores expertos responsables de cada uno de los grupos de trabajo participantes en el proyecto.

Entre los objetivos del proyecto está transferir el conocimiento y los desarrollos tecnológicos alcanzados durante su ejecución mediante actividades de divulgación y formación, como cursos y jornadas técnicas nacionales e internacionales. Así la Fundación Cajamar y el IFAPA de La Mojonera organizan un curso sobre transferencia de los resultados del proyecto que se realizará en Almería en las instalaciones de ambas entidades.

El curso va dirigido a estudiantes de doctorado y master de especialización en agricultura protegida, personal de centros de investigación, así como profesionales y técnicos del sector agroalimentario.

USO EFICIENTE DE *INPUTS* EN HORTICULTURA PROTEGIDA

7 de febrero de 2012 Martes

08:30.- Presentación del curso

09:00.- Nuevos desarrollos en materiales de cubierta para invernadero
Dr. Juan C. López (Fundación Cajamar)

11:00.- Desayuno

11:30.- Desarrollos del proyecto para invernaderos de cristal con cultivo de rosas
Dra. Nieves García (Wageningen U. R.)

13:30.- Almuerzo

15:00.- Energía y ventilación
Dr. Esteban Baeza (UAL)
Dr. Juan I. Montero (IRTA)

17:00.- Visita ensayos Estación Experimental de Fundación Cajamar

8 de febrero de 2012 Miércoles

08:30.- Enriquecimiento y manejo de CO^2 en invernadero
Dra. Cecilia Stanghellini (Wageningen U. R.)

10:30.- Desayuno

11:00.- Sistemas cerrados de cultivo hidropónico
Dr. Alberto Pardossi (UNIPI)
Dr. Luca Incrocci (UNIPI)

13:30.- Almuerzo

15:00.- Análisis económico y ciclo de vida de los distintos sistemas de invernadero
Dra. Assumpció Antón (IRTA)

17:00.- Visita ensayos Centro IFAPA La Mojonera

9 de febrero de 2012 Jueves

VISITAS TÉCNICAS

08:30.- Visita finca con instalación de cogeneración (El Alquian)

10:30.- Desayuno

11:30.- Visita fábrica de films plásticos SOTRAFA

13:00.- Visita planta solar de detoxificación y reciclaje de envases de fitosanitarios CESPA

14:30.- Clausura de curso. Almuerzo

Appendix 3.

Announcement for a Technical Seminar in Almería in February 2012, Spain.

Appendix 4.

Poster for the Tecnical Trials during the Hortifair 2011, The Netherlands.

WAGENINGEN UR
For quality of life

Effect of AR coated, diffuse greenhouse glass cover on rose production and quality

Nieves Garcia, Tom Dueck, Margreet Bruins, Peter van Weel, Frank Kempkes, Cecilia Stanghellini

Introduction

Energy consumption in rose cultivation in The Netherlands is high, as artificial light must supplement scarce sun radiation. But too high radiation can reduce flower quality, so shading is applied in spring, summer and autumn to protect the crop from damage. A diffuse glasshouse cover with anti-reflection coating could decrease the need for shading in rose production. To find out, an experiment was conducted by Wageningen UR Greenhouse Horticulture in Bleiswijk from august 2010 till september 2011.

Figure 1: Greenhouse with Diffuse+AR glass cover

Materials and Methods

Young plants of the rose 'Red Naomi!' were cultivated according to commercial practice in two greenhouse compartments, one with diffuse glass (*table 1*).
Plant effects as well as environmental and economic implications were evaluated.

Table 1, glass cover properties

	REFERENCE	DIFUSE+AR
Haze %	72%	0%
Transmission (perp.)	90%	93%
Transmission (hemf.)	83%	83%
Greenhouse transm.	59%	60%

Main results

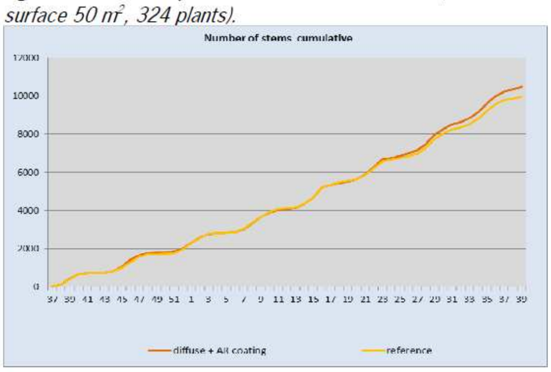
The screening requirement was reduced with 100 W/m² outside radiation in the difuse+AR compartment (*figure 1*) as compared to the reference. Despite less screening, quality problems associated with high radiation (petal edge blueing, *figure 2*, and leaf-tip burning, *figure 3*) are equal or even reduced.

Figure 2, petal blueing

Figure 3, leaf tip burning

The production increased by 5% in number of stems in the diffuse glazed greenhouse *figure 4*,; stem weight and length are slightly higher.

Figure 4: cumulative production in number of stems (total surface 50 m², 324 plants).



Conclusions

- Reduction of need for screening
- Positive effect on flower quality
- Higher production (5,2% in stems, 6% in weight)
- Slightly higher stem length and weight
- Better crop quality (according to involved growers)
-

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