Energy Efficient Climate Control for Cut Flower *Alstroemeria*

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Abstract

Like in most countries, in the Netherlands energy consumption is an increasing cost component. In cut flowers grown at a relatively low temperature, most of the energy is used for dehumidification. In *Alstroemeria* dehumidification is especially important to prevent the physiological disorder expressed as necrotic leaf tips. Research has been carried out showing that improved climate control can save 37% on heating, without a reduction on yield and even a quality, compared to a contemporary reference. Showing less necrotic leaf tips, the quality was better in the greenhouse with the energy saving strategy in December and January. This result was realized with a novel dehumidification system, a double thermal screen and temperature integration. When vapour pressure deficit was below 1.9 g/m^3, outside air was blown under the canopy with an air distribution system for dehumidification. If necessary, this outside air was first heated to greenhouse temperature to prevent an inhomogeneous temperature distribution. The reference greenhouse, controlled at the same humidity set point, used a combination of slightly opening the thermal screen followed by slightly opening the vents to carry off moisture. Eventually, at a vapour pressure deficit of 1.5 g/m^3 the temperature of the heating pipe was risen to lower the humidity. In the greenhouse with the energy saving concept no heating pipe for dehumidification was needed. The performance of the energy saving concept proved to be efficient.

INTRODUCTION

Climate control in greenhouse horticulture is needed to improve yield and quality. Heating and dehumidification of glasshouses requires energy, which is an uncertain and increasing cost (van der Velden and Smit, 2009; Hermosilla et al., 2010). Agreement between the Dutch government and the sector is to reduce the use of fossil energy (LNV, 2008). Temperature integration and increment of insulation by the application of thermal screens are methods to reduce the energy need for climate control in glasshouses. However, energy saving by these measures is limited by humidity control if the usual fixed set points are maintained (Korner and Challa, 2004). Less vapour exchange from ventilation and less condensation on the cover through lower night temperatures result in higher humidity, which normally result in a more frequent opening of the vents. In cut flowers grown at a relatively low temperature, the humidity is already close to levels that cause problems with fungus and physiological disorders of the leaves. In common practice, temperature and humidity are controlled by heating and ventilation by slightly opening thermal screens and vents. Disadvantages of this method are the horizontal temperature differences it causes and the energy consumption (Campen et al., 2009). An alternative system for humidity control is an air distribution system as described by (Campen et al., 2009). With this system, a well controllable amount of outside air can be directed to the place where drying of the air is most wanted (i.c. close to the most vulnerable parts of the canopy). This outside air is heated to greenhouse temperature and distributed via perforated ducts with a diameter of some 10 cm (Fig. 1). Since outside air

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has a lower absolute humidity than greenhouse air for most of the time, this relatively dry air will decrease humidity in those vulnerable regions. Experiments with tomato and cucumber with this system already proved 18 to 40% reduction in energy consumption without humidity problems and with equal yield (de Gelder et al., 2010a, b). In cut flowers grown at a relatively low temperature, the demands on a humidity control system are even tougher. Besides the higher risks with low temperature, in many cut flowers there is less space between the crop than in vegetables, so diameter of ducts for air distribution have to be smaller. Next to fungal diseases, physiological disorders affecting the ornamental value make it important to prevent humidity problems. In cut flower *Alstroemeria* experience is that necrotic leaf tips (Fig. 2) appear at low vapour deficit (VD).

The aim of this research is to reduce energy consumption for heating and dehumidification in *Alstroemeria* with 40%, without a decrease in production and quality. To achieve this, temperature integration, a double thermal screen and the humidity control system with outside air were applied in a comparative greenhouse experiment.

MATERIALS AND METHODS

First a desk study was carried out to develop an energy saving concept for cut flowers grown at a relatively low temperature. To predict the energy saving potential of the different energy saving methods the KASPRO model was used (Zwart, 1996). This model is an extensively calibrated and validated dynamic physical simulation model. Energy consumption was calculated with set points according to common practices as reference and with set points based on the energy saving methods. These methods were temperature integration (with positive and with negative DIF) a double thermal screen and accepting higher humidity (implemented by shifting the threshold for humidity control by 5% RH-points as compared to common practice).

Secondly a one year greenhouse experiment was carried out with *Alstroemeria* in two glasshouses of 144 m^2 at the research facility of Wageningen UR Greenhouse Horticulture, location Bleiswijk, The Netherlands. In one greenhouse, climate control was based on the developed energy saving strategy and in the other greenhouse climate control was based on nowadays practices. Average temperature, VD and light sum was kept as equal as possible in both greenhouses. The applied energy saving concept consisted of a) temperature integration with a heating set point of 12°C and less ventilation instead of a heating set point of 14°C, b), a second thermal screen (transparent and high insulating) and c) dehumidification when VD was below set point with outside air distribution instead of opening screens and vents. With this humidity control system outside air is blown into the bottom parts of the canopy with maximal flowrate of ±7 m^3 m^{-2} hr^{-1}. In the main supply, a heat exchanger was mounted to preheat this air to the greenhouse air temperature. The distribution took place with three plastic ducts per 1.6 m, each having a length of 13 meter and a diameter of 100 mm. The ducts were perforated with 4 mm diameter holes evenly distributed over the duct every with 14 holes m^{-1}. Actions for dehumidification started in both greenhouses at the same VD set point (varying between 1.4 to1.9 g/m^3 over the seasons). The reference practice for dehumidification was slightly opening the thermal screen followed by slightly opening the vents. At a vapour pressure deficit of 1.5 g/m^3 a heating pipe was used to lower the humidity. At outside air temperature above 5°C a minimum vent opening of 2% was applied in reference greenhouse.

Planting was at 14th of April 2009 on cocopeat with soil cooling in summer. This cooling kept the soil at 15.5°C. Additional lighting (SON-T) with an intensity 66 µmol $m^{-2}s^{-1}$ was used during winter period. The lamps are switched on for maximal 17 hours per day when outside radiation is below 170 W/m². Used cultivars were *Alstroemeria* 'Primadonna' and 'Virginia'. Each greenhouse was divided in four plots of 4 *1.60 m^2 of both cultivars. Flower production of each plot in number of stems and fresh weight was measured until 14th of April 2010. During the months of occurrence, necrotic leaf tips were counted.

RESULTS AND DISCUSSION

Energy Consumption

After one year, the heat consumption of the compartment with the improved climate control facilities was 37% lower in comparison with the reference greenhouse (Fig. 3). When scaled up to a commercial sized greenhouse, the yearly energy consumption for heating would be 5.1 m^3 of natural gas per m^2 per $year^{-1}$ compared to 8.7 m^3 m^{-2} $year^{-1}$ for the reference. Only a very small amount of this heat demand was used to preheat outside air when blown into the greenhouse for dehumidification (0.25 m^3m^{-2} $year^{-1}$). This was due to the fact that the air distribution system had to run only 200 hours per year. This is also the reason why it only consumed 1 kWh of electricity per m^2 per year. A factor analysis with the KASPRO simulation model indicates that almost half of the energy saving was realized by the improved heating strategy (temperature integration, occasionally made even more effective by adding negative DIF if this appears to be beneficial on a particular day). One third of the energy saving achieved can be attributed to the novel dehumidification system and the smallest contribution (one sixth) comes from the second thermal screen.

Yield and Quality

The energy efficient climate control did not significantly affect yield in number of stems, fresh weight and length of the stems. In December, January and February quality was higher in the greenhouse with improved climate control, because less necrotic leaf tips appeared (Fig. 4). More replications are needed to exclude coincidence.

Vapour Pressure

The humidity control system turned out to be able to control the VD most times. Only the nights when outside air was humid and at about the same temperature as the greenhouse, the VD fell back to values around 1.1 g/m^3. In the reference greenhouse, in such conditions, the VD reached 1.3 g/m^3. However, in general the VD in the energy saving greenhouse was maintained closer to the required set point than in the reference greenhouse.

When no heating pipe is used for heating, during night, the VD of the air at the bottom parts of the canopy was in general some 0.5 g/m^3 lower that the air at the top of the canopy. In the energy saving greenhouse with air circulation turned on, there was practically no vertical humidity distribution in the canopy. More replications are needed for statistical consideration.

In December the set point of the VD was lowered to 1.7 g/m^3 and half December to 1.4 g/m^3 in both greenhouses to be more close to regular growers. From half December until start of February in the reference greenhouse more necrotic leaf tips appeared in ‘Nadya’ and ‘Primadonna’ than in the energy saving greenhouse. From half February to April the number of leaf tips in both greenhouses was almost equal.

An exponential relation ($y=a+b*r^x$) was found between the duration of time the VP (x) was below 1.7 g/m^3 in the three weeks before the moment of counting necrotic leaf tips, and the number of necrotic leaf tips (y). The relative increase was equal for all cultivars (r=1.346, $P<0.05$). Also an exponential relation was found for the past three days instead of weeks before the moment of counting necrotic leaf tips (r=1.0038, $P<0.05$). Parameter b was for cultivar ‘Primadonna’ significantly ($P<0.05$) higher than ‘Virginia’, indicating ‘Primadonna’ is more sensitive to low VP than ‘Virginia’ for the appearance of necrotic leaf tips (Fig. 5). ‘Nadya’ was intermediate in sensitivity. This corresponds to experiences of growers and the larger leaf area and luxuriant growth of ‘Primadonna’ and ‘Nadya’ compared to ‘Virginia’.

Nutrient analysis of leaves showed a lower K/Ca-ratio in intact leaves than in leaves with necrotic leaf tips. Also the K/Ca-ratio was lower in energy saving greenhouse than in reference greenhouse. Not enough replication samples were possible for statistically sound results, but the results correspond to the theory that calcium is needed for stability of cell membranes. Growing plant parts, which are relatively ineffective in acquiring water through the transpiration stream, receive much of their nutrients and water via the phloem. Calcium is relatively phloem-immobile (Raven et al., 1999). A shortage of transpiration could result in deficiency of calcium in the membranes, making cells more vulnerable for climate fluctuations. The difference in water vapour pressure between the intercellular spaces and the surface of the leaf (VPD) influences the rate of transpiration (Raven et al., 1999). The humidity control with dry air close to the young growing plant parts in the energy saving greenhouse, could have slightly stimulated transpiration and calcium transport to the membranes and reduced fluctuations in VP within the canopy.

Temperature Integration and Additional Thermal Screen

From half December until half January instead of a positive DIF, a negative DIF in heating set point was used. Because of low natural temperatures, heating during night with closed thermal screens is more efficient than heating during day without a thermal screen or with a single thermal screen. During dark and cold periods, the difference in heating set point of 12°C compared to 14°C could not be compensated by less ventilation during daytime. To keep up with the same average temperature in the energy saving greenhouse as in the reference greenhouse, heating point was raised to 13°C.

CONCLUSIONS

Temperature integration, double thermal screens and humidity control with outside air heated to greenhouse temperature distributed within the canopy enables a saving of 37% on heating energy with an equal yield in *Alstroemeria.* For cultivar ‘Primadonna’ and ‘Nadya’ quality increased because less necrotic leaf tips appeared. The humidity control system makes it possible to control humidity more effectively, enabling energy saving methods as lower night temperatures and more insulation with thermal screens. Traditional greenhouses have difficulties in preventing high humidity within the canopy, especially in late autumn and early spring. The humidity control system reduces the VD gradient within the canopy in these periods. This enables to allow higher average humidity in a greenhouse with the humidity control system. Tolerating a higher humidity level helps to save energy, especially for highly insulated greenhouses.

An exponential relation was found indicating that the more often the VD comes below 1,7 g/m^3 in the three weeks or three days before counting necrotic leaf tips, the higher the number of necrotic leaf tips.

ACKNOWLEDGEMENTS

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Figures

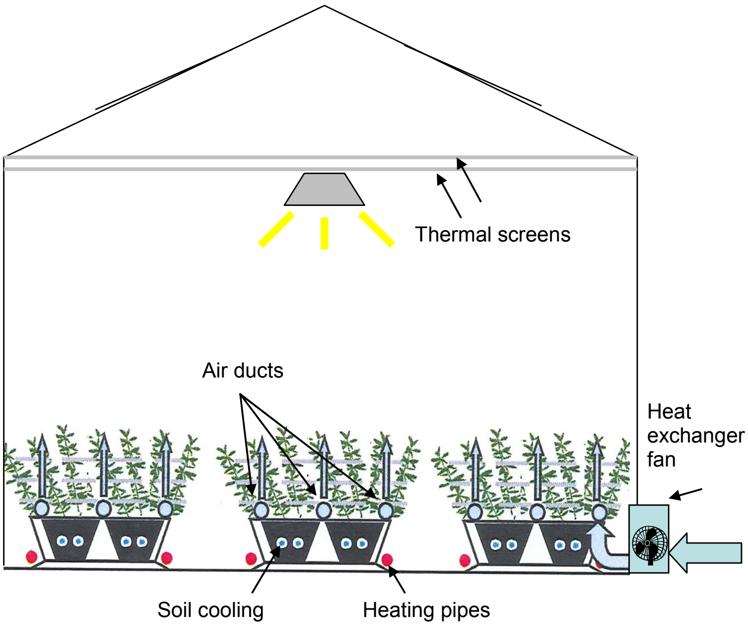

Fig. 1. Schematic representation of the novel dehumidification system where the ventilator and heat exchanger are located at the sidewall of the greenhouse drawing in outside air and distributing it via three plastic ducts per 1.6 m, each having a length of 13 m and a diameter of 100 mm.

Fig. 2. Necrotic leaf tips in *Alstroemeria* ‘Nadya’.

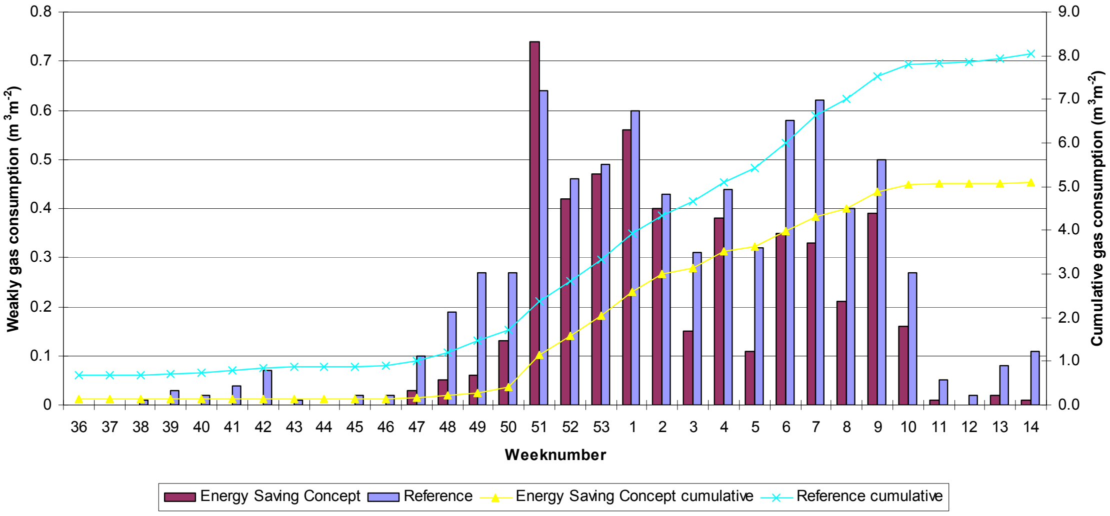

Fig. 3. Weakly gas consumption and cumulative gas consumption over a year from start of the experiment (week 16), shown from week 36 2009 until week 14 2010 of Energy Saving greenhouse and Reference greenhouse.

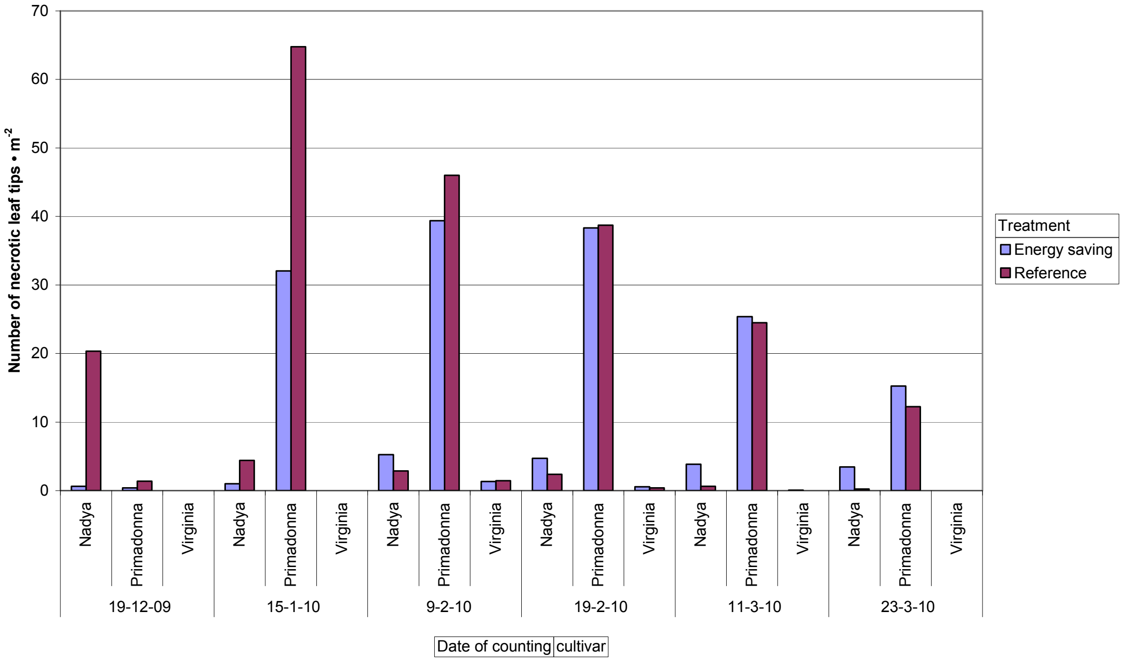

Fig. 4. Number of necrotic leaf tips in the canopy counted on several days during winter period in Energy Saving greenhouse and Reference greenhouse, for *Alstroemeria* ‘Nadya’, ‘Primadonna’ and ‘Virginia’.

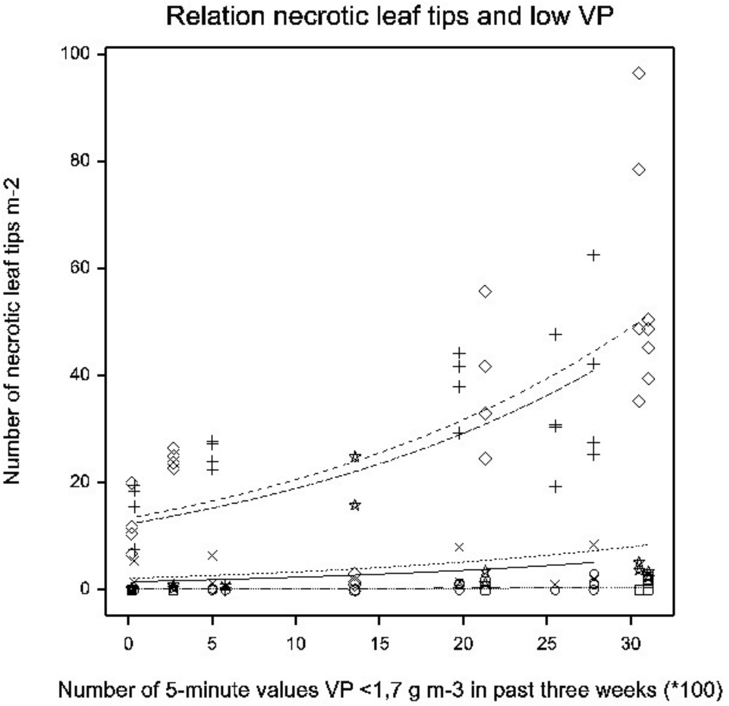

Fig. 5. Relation between number of 5-minute values vapour pressure was below 1,7 g/m^3 (x-axis) and the number of necrotic leaf tips in the canopy m^{-2} (y-axis) in the past three weeks before the moment of counting of necrotic leaf tips in Energy Saving greenhouse ‘Nadya’ (x), ‘Virginia’ (o), ‘Primadonna’ (+) and in Reference greenhouse ‘Nadya’ (*), ‘Virginia’ (□) and ‘Primadonna’ (◊).