Effect of a Diffuse Glass Greenhouse Cover on Rose Production and Quality

N. García Victoria, F.L.K. Kempkes, P. Van Weel, C. Stanghellini, T.A. Dueck and M. Bruins
Wageningen UR Greenhouse Horticulture
Bleiswijk
The Netherlands

Keywords: rose cultivation, covering material, diffuse glass, 'Red Naomi!'

Abstract

High energy use in rose cultivation at higher latitudes is caused by the need for artificial light to supplement scarce sun radiation. On the other hand, too high radiation levels are known to reduce flower quality. Therefore shading is widely applied during spring and summer, either through movable screens or seasonal whitewash. In both cases damage to the crop is avoided at the cost of reducing potential assimilation. Recent research on cucumber (Hemming et al., 2008a) has shown that diffusing cover materials improve the uniformity of vertical light distribution in a crop, therefore decreasing the energy load on the uppermost crop layer to the advantage of the underlying leaves avoiding light saturation in the upper leaves. These properties lead to an increase in production up to 10%. The application of such a cover on roses could decrease the need for shading so that a desired radiation sum could be achieved with less need for artificial light. Moreover, if the light distribution improvement on the crop leads to an increase in production, the same production could be achieved with less supplemental light, increasing the potential energy saving. Diffusion, however, usually implies a loss of overall transmission. This drawback can be avoided by antireflection coatings so that most recently diffusive glass covers have become available with the same transmission as standard glass. A rose crop ('Red Naomi!') was cultivated from August 2010 till September 2011 at the research station of Wageningen UR Greenhouse Horticulture in Bleiswijk in two compartments, one of them covered with diffuse, anti-reflection coated glass. This paper describes the effect of the diffusing cover on the photosynthetic properties of the crop, and the resulting production and quality.

INTRODUCTION

Light is not evenly distributed in glass greenhouses. 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 less light and contribute 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. 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. 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 structure that scatters the incoming light, 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 et al., 2005a, b). 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 et al., 2005b, 2008a) diffuse covers resulted in a more effective photosynthesis and better quality.

All but good reasons to test this new materials with the most important and most energy-demanding ornamental crop in The Netherlands: roses. An experiment started in 2010 to investigate the effect of diffuse covering materials on light distribution, plant photosynthesis, plant growth and development of a rose crop. The crop has a different plant architecture as the previously investigated vegetable crops. In summer rose crops are often shaded, as high (sun) light intensities in combination with 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). We discuss here the results of this experiment with roses in two greenhouse compartments, covered respectively with diffuse and standard glass.

MATERIALS AND METHODS

The experiment was conducted in 2 compartments (144 m^2) of a Venlo-type glasshouse, E-W oriented, located in Bleiswijk, western part of Holland. Each compartment composed of 2 spans, with north-south width of 4.8 m and east-west length of 15 m. Gutter height is 5.5 m; roof angle 22°. The soil is covered with anti-weed sheet, with the exception of a 1.2 m wide, concrete path situated along the entrance. One compartment was covered with standard glass whereas the other was covered (side walls included) with Vetrasol 503 diffuse glass with an Anti-Reflection coating (GroGlass) on both sides. The glass has in one side a prismatic structure, which is placed towards the inside of the greenhouse. In Table 1, the overall properties of these glasses and of the compartments are shown.

The rose plants (*Rosa hybrida* ‘Red Naomi!’) were propagated by cuttings using the Synchronization Method (Van Telgen et al., 2003) in Rockwool plugs (Grodan) and once rooted they were planted in May 28th in SPU (single production units) Rockwool blocks (Grodan) of 24×20×7.5 cm with 2 plants per block. Extended propagation allowed transport of the productive plants on August 26th to the experimental compartments with respectively clear and diffuse glass and placing on E-W oriented gutters, with a plant density of 6.2 plants/m^2. The plants were grown following the ‘bending’ technique (de Hoog et al., 2000) and irrigated by means of a drip system, automatically controlled by a fertigation computer. Water supply was scheduled based on drain percentage, solar radiation and crop stage. The nutritive solution used was the standard solution for Rose on Rockwool (De Kreij et al., 1997). CO_2 was supplied by means of injection during the light period to achieve 1000 ppm. Artificial lights (170 µmol/m^2/s) were used during part of the night and whenever the outside radiation dropped below 175 W/m^2 up to a maximum of 18 hours per day. Control of climate was in the winter the same for both compartments. In spring /summer shade screens (LS XLS 13 F) closed according to commercial practice when the outside radiation exceeded 600 W/m^2 in the reference (clear glass compartment) or 700 W/m^2 in the compartment with diffuse glass. Pest management was integrated: as much as possible by means of biological agents. Disease (powdery mildew *Sphaeroteca* *panosa*) was scored once every two weeks and controlled chemically.

From the second production flush (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 commercially accepted ripening stage for this variety. Each harvested stem was counted and weighted; its total 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.

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°C. After this post-harvest treatment, the flowers were transferred to a flower vase life testing room with conditions as internationally agreed for this purpose: 20°C, 60% RH, 12 h light per day at 14 µmol/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 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.

In November 2010, January 2011 and May 2011, photosynthesis of three plants per compartment was measured (Licor-6400 Photosynthesis meter). Two leaves were chosen from each plant: one on the vertical part of the canopy (harvestable stems) and the other on the horizontal part (the bent stems).

In addition, light interception by the crop at different heights of the canopy was measured twice, in January and in April in both compartments using a SunScan meter from delta-T. The amount Photosynthetic active radiation (PAR) was measured at different heights in the crop and compared to the PAR directly above the crop.

Throughout the growth period, climatic data were recorded at 5 min 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. The inside photosynthetic active radiation was measured with a Quantum sensor located just above the crop. Outside temperature, RH, solar radiation, wind speed and direction were recorded automatically by a weather station.

RESULTS AND DISCUSSION

The results discussed below include the harvest data belonging to one full cultivation year (first cropping year).

Production

The production results are shown in Figure 1A, cumulative production (weight), Figure 1B, cumulative production (number of stems) and Figure 2, production (stems) per week. 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 (up to 80% from December until February).

High radiation levels in March and April 2011 lead to quality damage of the crop, as at levels above ±1000 µmol/m^2.s (grower's experience, results shown in Kempkes et al., 2012), leaf tips heated up too much and dried, and blue edges appeared on the petals. These quality related problems decrease the market value of the roses and therefore, in commercial greenhouses shade screens are used to reduce the radiation. In our reference greenhouse, in consultation with the growers involved, we adopted the commercial threshold for screen closure: 600 W/m^2 outside radiation. In the glasshouse with the diffuse AR coated cover, we experimented with different thresholds and decided to close the screen when the outside radiation reached 700 W/m^2, 100 W/m^2 more than in the reference.

From May onwards, the differences in screening regime led to differences in total light integral that varied between 0 and 1.5 mol/m^2 per day and a small production advantage appeared in the diffuse greenhouse compared to the reference. This advantage amounted in August 343 stems (4% extra), more than one extra stem per plant, and kept on increasing until the end of the experiment (September 2011), so that in total, 513 more stems have been harvested in the diffuse greenhouse than in the reference greenhouse. This is 5.2% more stems and 6.1% more fresh weight. Stem quality (expressed as average length and average weight per stem) is comparable, as the stems harvested in both greenhouses have a length of 79 cm and a weight of 61 g. Bud size is with 4.5 cm in the reference greenhouse and 4.6 cm in the diffuse glazed greenhouse also comparable in both compartments. The measurement fields include 324 plants and cover a surface of about 50 m^2.

Photosynthesis

Net photosynthesis of plants in both compartments was comparable in all the measurements regardless of the season. Figure 3 shows the January and May results 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 can be observed (Schapendonk et al., 2009). Unexpectedly, no differences were found between the plants from both compartments; in previous research with vertical vegetable crops (Hemming et al., 2008a) the plants grown in diffuse light showed a higher net photosynthesis. The lack of differences in roses could possibly be explained by the crop architecture.

Light Interception

The light interception by the crop as it was measured in January is shown in Figure 4A; the April measurement is shown in Figure 4B. 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. Very little light is received at the bent canopy level. The resulting curves under the two types of glass cover, are nearly identical, regardless of the season. The curve shape is affected by 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 of more than 2 m.

Vase Life

The average vase life of the flowers from both compartments varied between 16.3 and 18.5 days (Fig. 5). The main reason for termination of vase life was wilting. Flower opening was good to very good (stage 4.5 to 5 in a scale from 0= tight bud to 5= fully opened flowers) at all data. No significant differences were found in the vase life of the roses as a consequence of the greenhouse glass cover of the compartment were they were grown.

CONCLUSIONS

The diffuse glass greenhouse cover with Anti Reflection coating on both sides of the glass had a positive influence on the production of the rose 'Red Naomi!'. Compared to the reference greenhouse (clear glass), the diffuse glass compartment showed an increase in production of 5.2% in number of flowers and 6.1% in fresh weight. The average stem length, stem weight and bud length were not affected by the glasshouse cover. It is not possible to explain the positive effect on flower production by differences in light interception throughout the crop as a result of the glass cover properties as apparent in high wire vegetable production (Hemming et al., 2008a), neither by an increased photosynthetic capacity of the plants grown under the diffuse glass cover. The diffuse anti reflection coated greenhouse glass cover made the light incidence inside the greenhouse less erratic (Kempkes et al., 2012), with less moments of extreme high and extreme low values. The smoother light did not result in differences in daily light sum, 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.

The diffuse covering material reduced the bud temperature on sunny days and the number of burned leaf tips (Kempkes et al., 2012), although this reduction was not enough to avoid bud overheating and screening excess sunlight proved still necessary. The vase life of the harvested flowers was not affected by the greenhouse cover type.

Compared to vertically growing vegetable crops (10% more production as mentioned before), the rose production increase as a consequence of the diffuse glasshouse cover is small. Model calculations (Schapendonk, et al., 2011) prior to the experiment also forecasted a production increase of 8.5% 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. The use of the screens and of artificial light in the greenhouse, the “memory effect” by which the biggest effect might appear later in the season and the plant architecture might all provide explanations for the fact that the results are smaller than expected. Another possible explanation might lie in the strong “flush” effect in the cultivation; this is a genotypic property linked to apical dominance, strongly determining production capacity, which is lower for varieties with high apical dominance (Trouwborst, 2010).

The results of this experiment and of a similar parallel experiment with tomato (unshaded), where an increase in production of 9% has been registered between December 2010 and August 2011 in the diffuse compartments compared to the reference compartment (J. Janse, 2011, pers. comm.), however, suggest that a higher increase in production could be achieved with rose varieties less sensitive to leaf tip burning and petal edge blueing, and for which the flush effect in production is less pronounced than the chosen cultivar ‘Red Naomi!’. Such other varieties might allow to further increase the radiance threshold for screening or even to totally avoid screening, allowing more chance for the properties of the cover to affect the crop.

With the obtained production increase of 5.2%, the examined glass (tempered, double-sided AR coated Vetrasol 503) can be economically feasible (Ruijs et al., 2010), 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).

ACKNOWLEDGEMENTS

Much of the work presented here has been carried out within the project EUPHOROS, co-funded by the European Commission, Directorate General for Research, within the 7th Framework Program of RTD, Theme 2 – Biotechnology, Agriculture & Food, contract 211457. The views and opinions expressed in this article are purely those of the writers and may not in any circumstances be regarded as stating an official position of the European Commission.

The project was co-financed by the Dutch Horticultural Board and by the Dutch Ministry of Economy, Agriculture and Innovation, under the program “Kas als Energiebron” (greenhouse as energy source). We are grateful to Leo Oprel and Dennis Medema, the managers of the program, for their positive contribution.

Nico van Mourik, Mary Warmenhoven and Yafei Zhao are acknowledged for their skillful technical assistance; Gerard van der Broek and Peter Schrama for the crop management; the three commercial rose growers and the advisor involved (advisory board) are acknowledged for the interesting discussions and their cultivation recommendations.

Literature Cited

DeLucia, E.H., Nelson, K., Vogelmann, T.C. and Smith, W.K. 1996. Contribution of intercellular reflectance to photosynthesis in shade leaves. Plan, Cell and Environment 19:159-170.

Dieleman, A., Meinen, E., Warmenhoven, M., Steenhuizen, J., Uenk, D., Chizhmak, S. and Visser, P. de. 2007. Efficiëntie van groeilicht gedurende het etmaal Nota 490, Wageningen UR Glastuinbouw.

Farquhar, G.D. and Roderick, M.L. 2003. Pinatubo, diffuse light and the carbon cycle. Science 299:1997-1998.

Gu, L., Baldocchi, D.D., Wofsy, S.C., Munger, J.W., Michalsky, J.J., Urbanski, S.P. and Boden, T.A. 2003. Response of a Deciduous Forest to the Mount Pinatubo Eruption: Enhanced Photosythesis. Science 299:2035-2038.

Hemming, S., Dueck, T., Marissen, N., Jongschaap, R., Kempkes, F. and van de Braak, N. 2005a. Diffuus licht – Het effect van lichtverstrooiende kasdekmaterialen op kasklimaat, lichtdoordringing en gewasgroei. Wageningen UR report 557.

Hemming, S., van der Braak, N., Dueck, T., Elings, A. and Marissen, N. 2005b. Filtering natural light by the greenhouse covering – More production and better plant quality by diffuse light? Acta Hort. 711:105-110.

Hemming, S., Dueck, T., Janse, J. and van Noort, F. 2008a. The effect of diffuse light on crops. Acta Hort. 801:1293-1300.

Hemming, S., Mohammadkhani, V. and Dueck, T. 2008b. Diffuse greenhouse covering materials -material technology, measurements and evaluation of optical properties. Acta Hort. 797:469-476.

Hoog, J. de, Warmenhoven, M., van Mourik, N.M., Eveleens-Clark, B., Beelen, C. and Dijkshoorn-Dekker, M.W.C. 2000. Teeltmethodes Roos: Knipmethode, plantdichtheid en inbuigen. PBG rapport nr. 208.

Hovi, T., Nakkila, J. and Tahvonen, R. 2004. Interlighting improves production of year-round cucumber. Scientia Horticulturae 102(3):283-294.

De Kreij, C., Voogt, W., van den Bos, A.L. and Baas, R. 1997. Voedingsoplossingen voor de teelt van roos in gesloten teeltsystemen. Brochure 4, PGB.

Kempkes, F.L.K., Stanghellini, C., García Victoria, N. and Bruins, M. 2012. Effect of diffuse glass on climate and plant environment: first results from an experiment on roses. Acta Hort. 952:255-262.

Lakso, A.N. and Musselman, R.C. 1976. Effects of Cloudiness on Interior Diffuse Light in Apple Trees. J. Amer. Soc. Hort. Sci. 101(6):642-644.

Reid, M.S. and Kofranek, A.M. 1981. Recommendations for standardized vase life evaluations. Acta Hort. 113:171-174

Ruijs, M.N.A. and Montero J.I. 2011. Euphoros 3rd year report WP1, internal report.

Schapendonk, A.H.C.M., Pot, C.S. and Rappoldt, C. 2009. Plantenpaspoort roos, Sleutel voor optimale productie. Plantdynamics Rapport.

Schapendonk, A.H.C.M., Rappoldt, C., Pot, C.S. and Trouwborst, G. 2011. Diffuus Licht Roos Tussentijds verslag. Plantdynamics report.

Sheehy, J.E. and Chapas, L.C. 1976. The Measurement and Distribution of Irradiance in Clear and Overcast Conditions in Four Temperature Forage Grass Canopies. J. Appl. Ecol. 13(3):831-840.

Trouwborst, G., Pot, C.S. and Schapendonk, A.H.C.M. 2010. Haalbaarheid van LED-tussenbelichting bij roos: praktijkonderzoek op Marjoland. Plantdynamics report.

Van Telgen, H.J. et al. 2003. Naar een planmatige teelt van rozen. PPO intern verslag nr. GT 13 3006.

Vogelmann, T.C., Bornman, J.F. and Yates, D.J. 1996. Physiologia Plantarum 98:43-56.

Tables

Table 1. Transmission (perpendicular and hemispheric) and haze of the two cover materials and the overall transmission of the greenhouse compartment covered with each one.

Material	τ Perpendicular	τ Hemispheric	Haze	τ Compartment
Reference	90	83	0	59
Diffuse	93	83	72	60

Figures

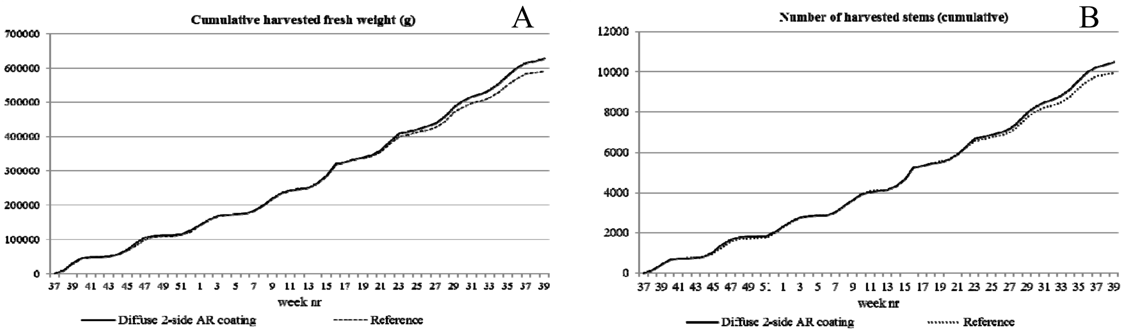

Fig. 1. Cumulative production in number of stems (A) and cumulative fresh weight production (B) in both compartments during the whole harvest period (one year). The sinusoidal shape of the lines is due to the flush effect in the production.

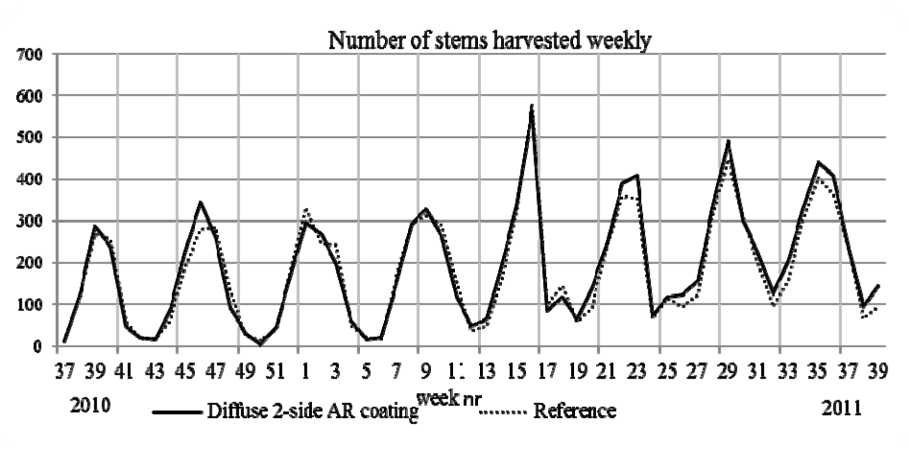

Fig. 2. Number of stems harvested per week in both compartments. The autumn and spring-summer weeks are the weeks where the diffuse glass cover has an influence on the total production. The lines show the strong flush effect.

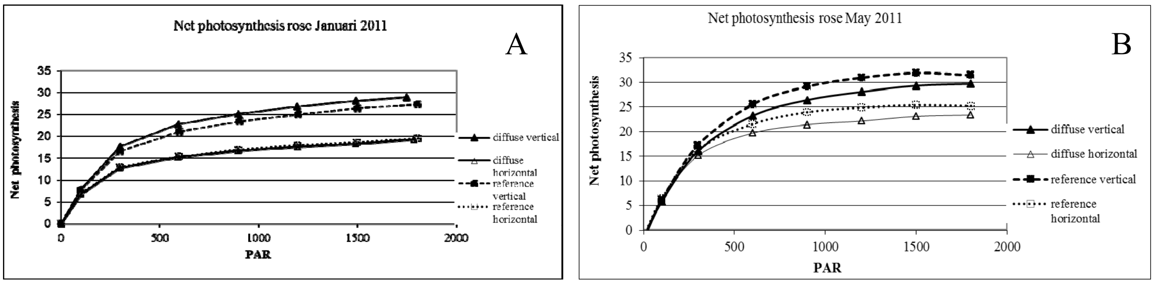

Fig. 3. Net photosynthesis of the crop in both compartments, in January (A) and in May (B). Open symbols: horizontal canopy leaves (belonging to the bent stems); closed symbols: vertical canopy leaves (belonging to harvest ripe stems).

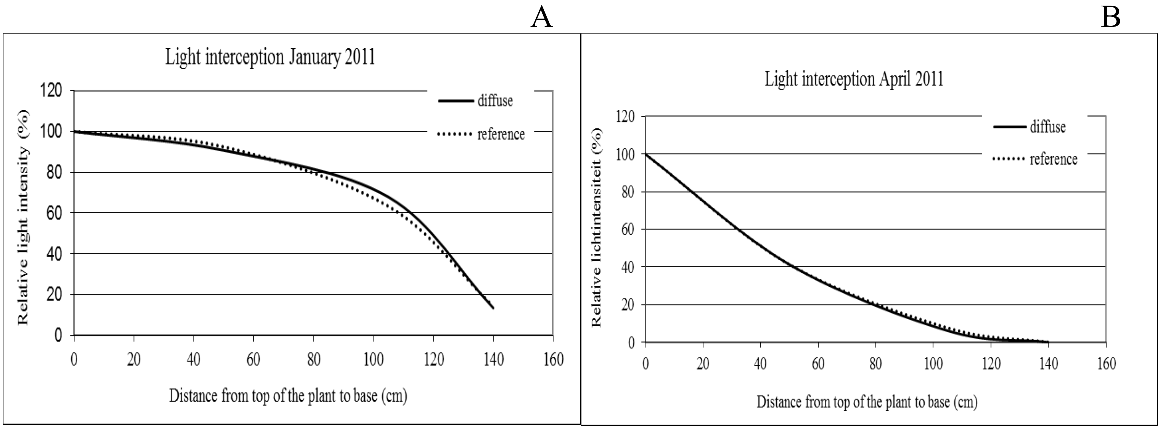

Fig. 4. Light interception by the crop at different heights in both greenhouses. A: situation in January; B: situation in April.

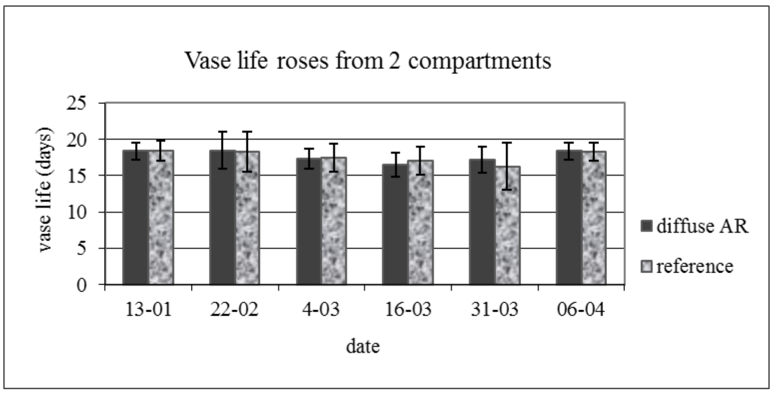

Fig. 5. Vase life of the harvested roses from both compartments at different harvest data. Values are means of 20 replicates.