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# Air Humidity Variation and Control of Vase Life and Powdery Mildew in Cut Roses under Continuous Lighting

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**Summary**

In this study the hypothesis that a variation in air humidity will reduce the negative effect of continuous lighting on keeping quality of cut roses without enhancing the development of powdery mildew, was evaluated. Vase life and water loss from detached leaves were studied in two cut rose cultivars grown at daily periods of 0, 6, 12 and 24 h at 62 % combined with 82 % relative air humidity (RH) under continuous lighting. In addition, the effect of constant low (62 % RH) and constant high (82 % RH) was studied at 18 h day$^{-1}$ lighting period. In continuous light, six hours with low RH considerably increased the vase life as compared with constant high RH in both cultivars. Extending the period with low RH from 12 to 24 h decreased the vase life particularly in cv. 'Orange Unique'. Reducing the lighting period from 24 to 18 h day$^{-1}$ significantly increased the vase life both at low and high RH. A close relationship was found between the vase life and control of leaf water loss from detached leaves in the different treatments. Reducing the lighting period increased the vase life and decreased the water loss from the leaves both at constant low and constant high air humidity. The development of powdery mildew was significantly reduced when the lighting period was increased from 18 to 24 h day$^{-1}$. The results are discussed in relation to produce cut roses with long vase life at a greenhouse climate that causes a minimum of powdery mildew development.

**Key words.** air humidity variation – cut roses – lighting period – powdery mildew – vase life – water loss

## Introduction

The vase life of cut roses is reduced by continuous lighting (Mortensen and Fjeld 1998; Mortensen and Gislerød 1999) and high air humidity (Mortensen and Fjeld 1998; Mortensen and Gislerød 1999), and is related to malfunctioning stomata and excessive water loss in indoor conditions (Mortensen and Gislerød 1999; Torre and Fjeld 2001). Recently, it was found that a daily six-hour period with low air humidity was sufficient to considerable enhance the keeping life of cut roses as compared to constant high humidity (Mortensen and Gislerød 2005). However, these studies were carried out at a lighting period of 20 h day$^{-1}$. It has so far not been investigated if a variation in the air humidity can counteract the negative effect of continuous lighting on vase life. In pot roses, however, it has been found that a daily six-hour drop in air humidity was sufficient to ensure the development of normal functional stomata under continuous lighting (Pettersen et al. 2007). Continuous lighting of roses is desirable since dark periods are known to enhance the development of powdery mildew as shown with pot roses (Mortensen and Braut 1998). This effect of a dark period on the development of mildew is probably related to a drop in air/plant temperature followed by a rise in air humidity. Variation in air humidity is known to cause powdery mildew (*Sphaerotheca pannosa* var. *rosae*) in roses (Tammen 1973; Wheeler 1978), which in turn significantly reduces the decorative value of the stems. Until now, however, continuous lighting has not been recommended due to the adverse effect on the vase life of cut roses. Therefore, it is of great interest both from a practical point of view as well as from a plant physiological point of view to investigate the effect of air humidity variations under 24 h day$^{-1}$ lighting period in cut roses. In order to do this, the cultivars 'Amadeus' and 'Orange Unique', known to be sensitive to high air humidity as well as to continuous lighting (Mortensen and Gislerød 1999), were used in the investigation.

Therefore, the hypothesis to be evaluated in this study was that a variation in air humidity will reduce the negative effect of continuous lighting on keeping quality without enhancing the development of powdery mildew.

## Materials and Methods

Old plants of the rose cultivars 'Amadeus' and 'Orange Unique' were cut back and replanted in a mixture of limed and fertilized peat (Humus-börsen), sand (5 % by volume) and perlite (33 % by volume) in 3-litre pots. They were grown under supplementary light, and after the first flush the plants were pinched at a height of 25 cm, and five pots of cv. 'Amadeus' and six pots of cv. 'Orange Unique' were placed in each of six growth chambers with a growing area of 2.5 m$^2$ each. The chambers were placed in a greenhouse compartment [previously described by Mortensen and Nilsen (1992)]. The inlet air

to the chambers came from a common air source, and the load with mildew spores was therefore the same in all chambers. The experiment included two lighting periods, 18 and 24 h day$^{-1}$ (continuous). Under 18 h day$^{-1}$ constant 62 or 82 % relative humidity (RH) were established, and under 24 h day$^{-1}$ 0, 6, 12 and 24 h with 62 % RH combined with 82 % RH was established in the different chambers. The relative humidities of 62 and 82 % corresponded to vapour pressure deficits (vpd) of 950 and 450 Pa, respectively. The humidity sensors (Vaisala HMP 35A) were calibrated using salt solutions of known concentrations (Vaisala HMK 11 Humidity Calibrator). The mean hourly RH level is shown throughout Flush 1 and Flush 2 in all treatments (Fig. 1). Such a detailed information was necessary for the understanding of the relationship between air humidity and plant responses with respect to water balance and vase life.

Supplementary lighting was given by high-pressure sodium lamps (Philips SON/T) at a photosynthetic photon flux of 150±20 μmol m$^{-2}$ s$^{-1}$ (corresponding to a pho-

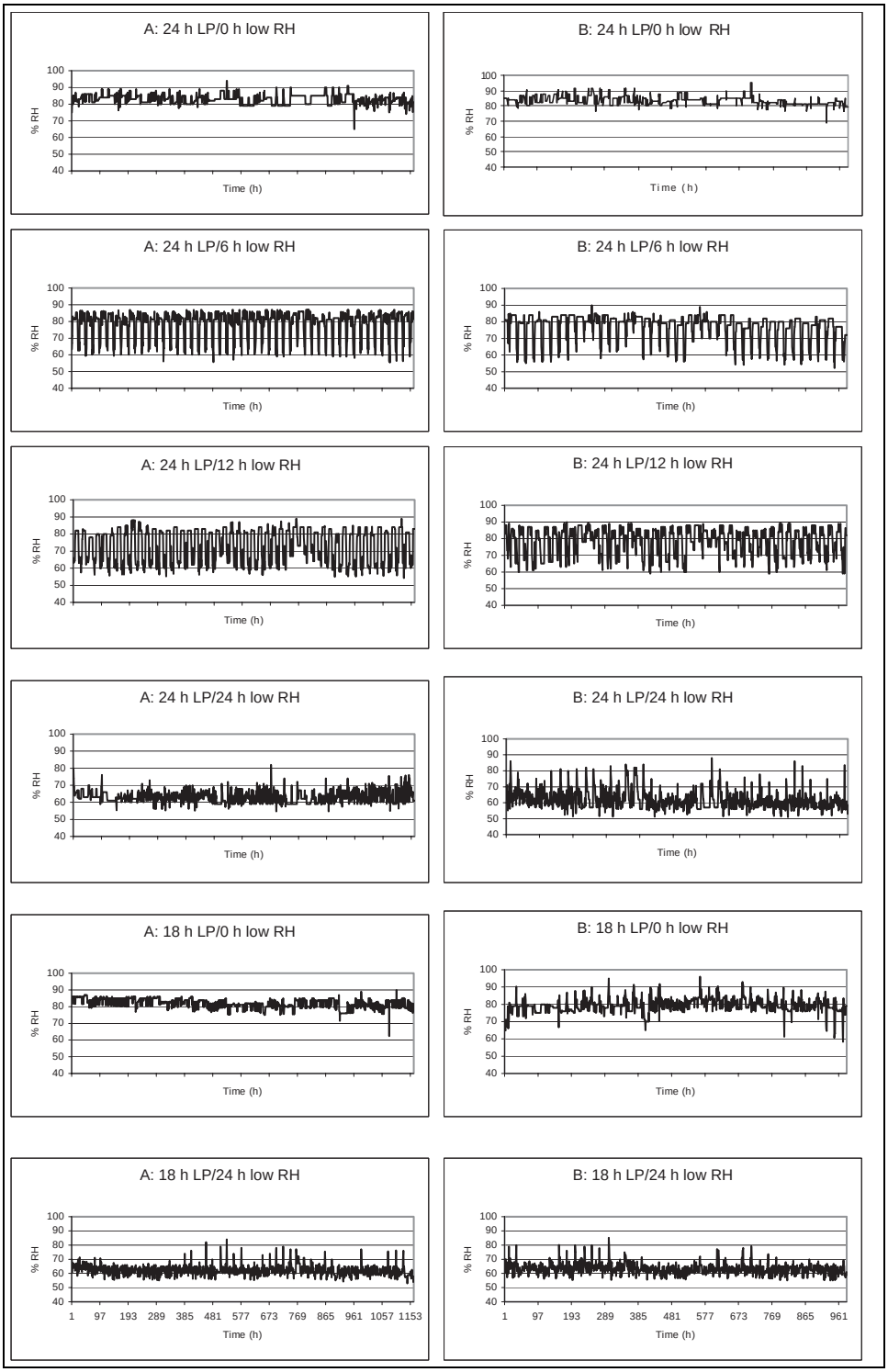



Fig. 1. Air humidity (% RH) given as hourly means in the different treatments in Flush 1 (A) and Flush 2 (B).

ton flux of 9.7 and 13.0 mol $m^{-2}$ $day^{-1}$ at 18 and 24 h $day^{-1}$ lighting period respectively). The light was measured with a Lambda LI-185B instrument with quantum sensor above the plants. The contribution by daylight in the chambers (approximately 50 % of the outside level) was on average 1.5 and 9.0 mol $m^{-2}$ $day^{-1}$ during first and second flush, respectively (Meteorological Station at Særheim Research Centre). The temperature in all chambers was maintained at 21.0±0.3 °C and the $CO_2$ concentration at 800±20 μmol $mol^{-1}$. The experiment started on 2 January and ended in the beginning of April. After the first flush (20 February) the treatments were switched between the chambers. Maximum five shoots were allowed to develop per plant. The plants were watered regularly with a complete nutrient solution as described previously (Mortensen and Fjeld 1998), and soil salinity was kept between 2.0 and 3.0 mS $cm^{-1}$, and pH about 5.5.

The rose shoots were harvested at flowering stage (flower bud opens), and their length, fresh weight and the development of mildew were recorded. Altogether 23–28 roses were harvested per treatment and cultivar.

Table 1. Effect of the length of the daily time period with low air humidity (62 % RH) combined with 82 % RH on vase life (days), on water loss (%) of detached leaves (after four hours) and on development of powdery mildew of two flushes of the rose cultivars 'Amadeus' and 'Orange Unique' at two lighting periods (LP).

| Cultivar | Flush | LP | Time with low RH (h $day^{-1}$) | | | | F-values and |
|---|---|---|---|---|---|---|---|
| | | (h) | 0 | 6 | 12 | 24 | significance levels |
| Vase life (days) | | | | | | | |
| 'Amadeus' | 1 | 24 | 2.7±0.3 | 7.2±0.7 | 6.2±0.7 | 5.2±0.6 | 10.3*** |
| | | 18 | 6.0±0.7 | – | – | 9.7±0.4 | 25.9*** |
| | 2 | 24 | 7.3±0.8 | 11.7±0.7 | 13.7±0.3 | 14.3±0.3 | 27.6*** |
| | | 18 | 13.8±0.3 | – | – | 9.2±0.5 | 53.6*** |
| 'Orange Unique' | 1 | 24 | 2.5±0.1 | 8.6±0.6 | 10.9±0.8 | 5.3±0.6 | 39.7*** |
| | | 18 | 4.4±0.5 | – | – | 11.9±0.7 | 77.8*** |
| | 2 | 24 | 2.9±0.3 | 12.1±0.8 | 13.5±0.7 | 14.3±0.5 | 83.7*** |
| | | 18 | 12.4±1.0 | – | – | 9.3±1.0 | 5.0* |
| Water loss (%) of detached leaves (after four hours) | | | | | | | |
| 'Amadeus' | 1 | 24 | 70±6 | 34±2 | 25±2 | 43±2 | 29.8*** |
| | | 18 | 37±3 | – | – | 19±1 | 32.4*** |
| | 2 | 24 | 58±2 | 26±1 | 23±1 | 21±1 | 151.0*** |
| | | 18 | 22±1 | – | – | 17±1 | 25.3*** |
| 'Orange Unique' | 1 | 24 | 69±3 | 35±3 | 23±2 | 40±2 | 68.7*** |
| | | 18 | 49±5 | – | – | 24±2 | 25.5*** |
| | 2 | 24 | 65±7 | 27±3 | 25±2 | 24±3 | 27.8*** |
| | | 18 | 24±2 | – | – | 25±3 | $0.1^{ns}$ |
| Development of powdery mildew | | | | | | | |
| 'Amadeus' | 1 | 24 | 0.3±0.2 | 0.1±0.1 | 0.1±0.1 | 0.4±0.1 | 2.99* |
| | | 18 | 1.1±0.2 | – | – | 1.4±0.3 | $1.37^{ns}$ |
| | 2 | 24 | 0.1±0.1 | 0.0±0.0 | 0.1±0.1 | 0.1±0.1 | $1.08^{ns}$ |
| | | 18 | 0.4±0.1 | – | – | 0.0±0.0 | 8.68** |
| 'Orange Unique' | 1 | 24 | 0.3±0.1 | 0.6±0.2 | 0.2±0.1 | 0.5±0.1 | 2.79* |
| | | 18 | 1.5±0.2 | – | – | 2.2±0.2 | 7.44** |
| | 2 | 24 | 0.0±0.1 | 0.1±0.1 | 0.0±0.0 | 0.1±0.1 | $1.34^{ns}$ |
| | | 18 | 1.0±0.2 | – | – | 0.8±0.1 | $1.56^{ns}$ |

Significance levels: ns, not significant ($p>0.05$); *, $p<0.05$; **, $p<0.01$; ***, $p<0.001$.
F-values and significance levels:
Vase life:
'Amadeus': Flush 1: LP=69.2***; RH=101***; LP x RH=20.6***; Flush 2: LP=7.38**; RH=25.9***; LP x RH=88.3***;
'Orange Unique': Flush 1: LP=62.6***; RH=39.5***; LP x RH=$1.65^{ns}$; Flush 2: LP=$1.01^{ns}$; RH=5.65*; LP x RH =109***
Water loss (%) of detached leaves (after four hours):
'Amadeus': Flush 1: LP=64.7***; RH=41.7***; LP x RH=$1.21^{ns}$; Flush 2: LP=341**; RH=384***; LP x RH=221***;
'Orange Unique': Flush 1: LP=41.3***; RH=88.6***; LP x RH=32.3***; Flush 2: LP=28.3***; RH=28.1***; LP x RH=31.2***
Development of powdery mildew:
'Amadeus': Flush 1: LP=32.8***; RH=$2.58^{ns}$; LP x RH=$0.26^{ns}$; Flush 2: LP=$1.69^{ns}$; RH=5.46*; LP x RH=5.46*;
'Orange Unique': Flush 1: LP=112***; RH=8.26**; LP x RH=$1.85^{ns}$; Flush 2: LP=56.7***; RH=$1.28^{ns}$; LP x RH=$2.28^{ns}$

The mildew attack was determined visually on a scale from 0 to 5: 0 = no visible mildew; 1 = 0–1 %; 2 = 2–5 %; 3 = 6–20 %; 4 = 21–60 % and 5 = 60–100 % infected leaf area. After harvest, 15 ('Orange Unique') or 18 cut roses ('Amadeus') were placed in vases (5 roses per vase) containing distilled water. The vases were placed in a room at 40±5 % RH (corresponding to 1500± 200 Pa vpd) and 21.0±0.5 °C to simulate indoor climatic conditions. Light at a level of 15 μmol $m^{-2}$ $s^{-1}$ photon flux was given for 12 h $day^{-1}$ by means of fluorescent lamps (Philips TL 33). Vase life was determined as the time until the rose lost its decorative value, i.e. the development of bent necks or flower wilting. At time of harvest, five leaves from the upper part of the shoots were picked off per plant in each chamber. The leaves were placed on a bench in the test room for keeping quality, and the water loss were determined by measuring the weight at start, after four hours and finally by determining the dry weight in an oven at 60 °C.

The experiment was analysed using the SAS-GLM procedure (SAS Institute Inc., Cary, USA). Shoots were used as replicates in the analysis. In the analysis of interaction between lighting period (LP) and RH only the treatments constant low RH and constant high RH were used.

## Results

The vase life was significantly longer with 18 h $day^{-1}$ lighting than under continuous lighting at constant low or constant high RH in the first flush (Table 1). In the second flush, the vase life was significantly increased with 18 h $day^{-1}$ lighting as compared to the first flush at constant high RH but not at constant low RH. Therefore, the vase life in the second flush at constant low RH was shorter with a 6-h dark period as compared to continuous lighting.

In both cultivars the vase life strongly increased under continuous lighting in both flushes when a 6-h period of low RH was given as compared with constant high RH (Table 1). In the first flush continuous low RH tended to reduce the vase life in both cultivars as compared with 6 or 12 h low RH, while in the second flush no such reduction was found.

A lighting period of 18 h $day^{-1}$ generally decreased the water loss compared to continuous light except in the second flush with constant low RH where the water loss was found to be low in both flushes (Table 1). The water loss from the leaves was strongly decreased under continuous lighting in both flushes when a 6-h period of low RH was given as compared with constant high RH. Further increase to 12 h low RH further decreased the water loss while 24 h low RH increased it again in first flush but not in the second.

When the vase life and leaf water loss from roses grown at the different treatments were plotted against each other a significant negative correlation appeared in cv. 'Amadeus' ($p<0.01$) as well as in cv. 'Orange Unique' ($p<0.001$) (Fig. 2). Roses with a low water loss generally had a long vase life, and at increasing water loss a linear decrease in vase life took place. No roses with a high water loss have a long vase life, but the vase life in roses with a low water loss can vary considerable. This means that if all roses with a vase life longer than 10 days was removed from the analysis, $r^2$ increased significantly (data not presented).

The development of powdery mildew was always very low in continuous light in both cultivars (Table 1). With a lighting period of 18 h $day^{-1}$ (6 h dark period) the mildew infection was significantly increased as compared with in continuous lighting except in cv. 'Amadeus' in the second flush. Increasing the RH from 62 % to 82 % in different time intervals had small or no effect on the development of powdery mildew in the two cultivars.

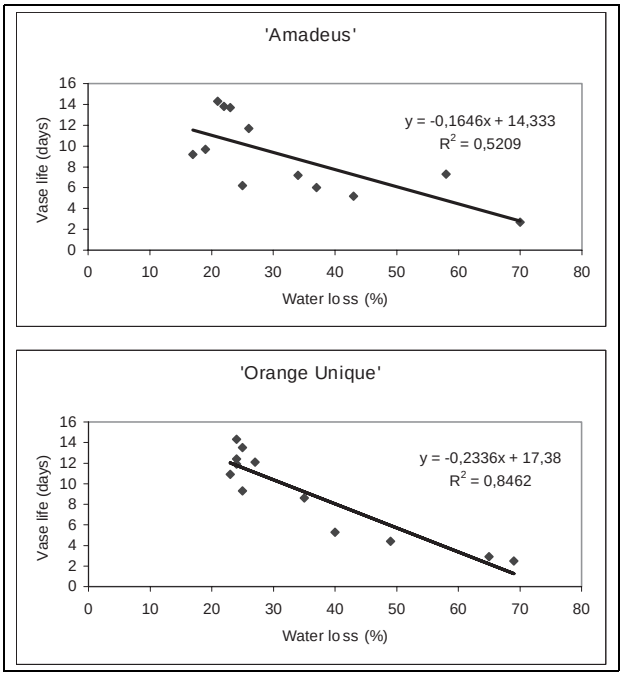



Fig. 2. Relationship between vase life and water loss from detached leaves (n=12) in 'Amandeus' and 'Orange Unique'. Significance level of r-square and regression function for cv. 'Amadeus' was $p<0.01$ and for cv. 'Orange Unique' $p<0.001$.

## Discussion

The present results show that it is possible to grow roses under continuous light without adversely affect the vase life if the air humidity is dropped during a daily 6-h period. This finding probably will have a great positive influence on the rose production where powdery mildew is a problem and artificial lighting is used to increase the rose yield (Mortensen and Gislerød 1994). Recently, it was shown that a 6-h drop period in air humidity was sufficient to enhance the keeping quality of roses grown with a lighting period of 18 h $day^{-1}$ (Mortensen and Gislerød 2005), and a similar effect has now proved true also under continuous lighting. The development of powdery mildew was reduced when the dark period was excluded by continuous lighting, in accordance with previous results with pot roses (Mortensen and Braut 1998). It is interesting to note that even with a 12 h/12 h variation between low and high RH, the development of powdery mildew was low in the present experiment with continuous lighting. Such a RH variation normally strongly en-

hance the development of mildew when the roses are grown at 18 h day$^{-1}$ lighting period (Mortensen and Gislerød 2005).

As shown in several reports the vase life of roses is closely linked to the ability of the leaves to control water loss at indoor conditions (Mortensen and Gislerød 1999; Torre and Fjeld 2001; Torre et al. 2001). Such a relationship has also been found in roses from a range of greenhouses, and measurements of water loss from detached leaves has often proved to be a very good method to evaluate the potential keeping quality of cut roses (Mortensen 2001). Also in the present study the vase life could generally be explained by the rate of water loss from detached rose leaves. However, below water loss rates of about 30 % per four hours, vase life seems to be influenced by other factors than water loss rates.

Generally, the same conclusions could be drawn from Flush 1 and 2 with respect to vase life. However, the decrease in vase life by increasing the time period with low RH from 12 to 24 h day$^{-1}$ found in Flush 1 was not found in Flush 2. Detailed analysis of the hourly RH values showed that the air humidity varied more during Flush 2 than during Flush 1, although the mean RH was the same (62–63 %). In Flush 2 the RH exceeded 70 % during 2.3 h per day as average, while in Flush 1 the respective number was 0.7 h per day. This variation was probably enough to stimulate the stomata function and control of water loss, resulting into a long vase life. It should be noted that it is the climate conditions during leaf development that determines the water loss after harvest of the roses (Mortensen and Gislerød 2000). This means that it is the period 10–20 days before harvest that is the most important period with respect to the influence of air humidity on vase life, since it is in this period that the most dominant leaves in the vase (upper five-leaflet leaves) of the rose shoot develop. The general longer vase life of the roses in Flush 2 than in Flush 1 can probably be attributed to much higher solar radiation during the last weeks of Flush 2. This might have caused a more variable microclimate around the leaves that stimulated the stomata function, resulting into reduced water loss and improved vase life.

From the present study it might be concluded that a relative short-term variation in air humidity will significantly extend the vase life of roses under continuous lighting without enhancing the development of powdery mildew. These results support the hypothesis that was established for this work. The change in RH caused a change in vpd of the air by about 500 Pa, however, during mild weather periods in spring and autumn it can be difficult to change the vpd that much by ventilation in practise. An interesting question is therefore if a periodical air temperature increase which increases vpd will have a similar effect as a drop in air humidity at constant temperature. In case, this might be an even better way to control keeping quality under continuous lighting.

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