

Mobile Light in Roses

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Abstract

In order to quantify the claimed differences between mobile and static lighting, and to clarify the mechanisms causing these differences, an experiment with rose ‘First Red’ was carried out. In a greenhouse compartment half of the area was equipped with mobile lamps, and the other half with static lamps. By mounting the lamps in the centre of the greenhouse, a light gradient was achieved in both treatments. Experimental plots were chosen with daily light integrals of 1 to 3 and 3 to 5 mol m⁻² day⁻¹ respectively. A ‘traditional’ and a ‘synchronous’ (production in flushes) crop were grown. Production and photosynthetic characteristics were measured during the winter season 2003 – 2004. Photosynthetic characteristics were measured in the synchronous crop. With the INTKAM simulation model for rose, production under diverse mobile lighting regimes was predicted. Fresh weight production over the experimental period was higher in the static-light treatment than in the mobile-light treatment for both the traditional as well as the synchronous crop. This was caused by a lower number of stems per plant and a slightly lower weight per stem under mobile lighting. Length of stems was not affected. The light response curves for leaves did not differ between the treatments. Also, the induction of photosynthesis after a simulated light pulse in a cuvette was the same for both treatments. Simulation of the growth of the synchronous crop showed that a different lamp speed or a combination of fixed and moving lamps confirmed the conclusion that mobile lighting did not lead to increased production in comparison with static lighting at similar daily amounts of lamplight.

INTRODUCTION

Mobile assimilation light has often been claimed to be more effective in terms of plant growth than static illumination. This was mentioned for several greenhouse crops, like Gerbera and rose, although quantitative support was not published. If so, the use of mobile lamps would require less energy for growth and production, and thus could be an opportunity to save energy consumption in rose culture. However, solid foundations for this statement have never been given.

Three physiological hypothesis have been emitted for the positive effects of variation in light intensity. A first hypothesis is based on negative feedback on photosynthesis which occurs under prolonged leaf exposure to high light level causing chloroplastic starch accumulation. This mostly happens when sink strength is low. Another theory includes a more efficient use of the daylight by leaves that are exposed to an intermittent extra light pulse (Chazdon and Percy, 1991). This situation occurs for plants under a canopy, where sun flecks cause spells of occasional high radiation in a generally low-light level growth situation. A rapid response of both photosynthesis and stomata and post-illumination CO₂ fixation could cause an increase in light-use efficiency. A third theory consists of the temperature-increasing effect of the lamps in the crop. Since the mobile lamps are mounted closer to the crop, the heat radiation is stronger, when the lamp passes over the plants. This causes a temporary increase of plant temperature. For a rose crop this could mean that bud break, a temperature-dependent process, is promoted.

In order to verify these assumptions, the photosynthetic responses of a rose crop

grown under mobile and static lighting were measured. Also, the production was measured.

In this experiment the daily light integral used was identical for both light treatments, static or mobile lamps.

MATERIALS AND METHODS

In two greenhouse compartments of 300 m² each, roses 'First Red' were grown on rockwool, using a nutrient solution with an average pH of 6.65 and EC 2 mS cm⁻¹. Plant density was 6 plants per m². Two different types of rose plants were used: a traditional plant, obtained from a commercial propagator, and 'synchronised' cuttings. The synchronisation of these cuttings was obtained by a registered method, causing a simultaneous bud break and maintaining only two shoots per plant. Subsequent flushes of bud break and shoot growth were thus synchronised, enabling a harvest period of 2 to 4 days per flush. This procedure enables physiological comparisons within a crop, since all harvestable stems are of the same age. All plants consisted of bent stems, forming a canopy of leaves which act as a source of assimilates for the harvestable stems. Roses were planted in week 35 (2003), harvesting started in week 46 (2003) and the experiment was stopped in week 16 (2004). Setpoint for the greenhouse air temperature was 20 °C day and night. CO₂ was applied to a maximum concentration of 700 ppm when the vents were closed.

Half of each greenhouse was equipped with mobile lamps, the other half with static lamps. The lamps were mounted in a row in the centre of the greenhouse in such a way that a light-intensity gradient was realised towards the sides of the greenhouse. The treatments were replicated in mirrored order in the other greenhouse compartment. The mobile lamps were mounted 1.8 m above the rooting medium of the plants in one half of the greenhouse. Lamp speed was 0.5 m min⁻¹ on the onward way and return speed was 5 m min⁻¹. This resulted in a light pulse with a maximum intensity of $\pm 260 \mu\text{mol m}^{-2} \text{s}^{-1}$ (Fig. 1). The other half of the greenhouse was equipped with static lamps at 3 m above the rooting medium. By detailed measurements experimental plots were determined with comparable daily light integrals of the supplementary lighting of a high and a low light sum of 3 to 5 and 1 to 3 mol day⁻¹ for both light treatments.

Production was recorded by daily measurements of the number of harvested stems, stem length and stem weight. Recording started in week 46 (2003) and stopped in week 16 (2004). The differences were tested with regression analysis. We used generalised linear mixed models (GLMM's) to account for non-normal probability distributions and for correlations related to the blocking structure. Plant temperature was measured with an infrared camera (Heimann, Germany).

Light-response curves were measured simultaneously in both greenhouse compartments using a LI-6400 (Licor, Lincoln, Nebraska, USA). Intact stems of the same age on synchronous plants were used. Conditions in the measuring cuvette were set equal to the conditions in the greenhouse. Growth of the rose crop with different mobile light regimens was simulated with the INTKAM model. The light response curves as mentioned above were used to calibrate the model. Also data of the greenhouse climate and light measurements were used. For the static lamps the photosynthesis was calculated on an hourly basis, for the mobile lighting photosynthesis was calculated per minute.

RESULTS AND DISCUSSION

The production of traditionally grown roses with static lighting was higher than with mobile lamps (Table 1). This result is mainly caused by a greater number of stems allowed to grow on the traditional as compared to the synchronous crop. Furthermore, yield is significantly higher under static light treatment when reported as total fresh weight in g per m² of harvested roses as compared to mobile light treatment (Table 2). Stem weight and length were not influenced by the type of lighting treatment. An average stem length of 53 cm was measured and was not influenced by the mode of lighting.

The presumed increase of the efficiency of the photosynthesis was not observed.

The light response curves of leaves grown with static or with mobile lamps were equal (Fig. 2). The only difference observed between mobile and static lighting occurred in a synchronous crop shortly after the previous flush had been harvested. For these measurements leaves of the bent stems were used. Here a decrease of the light response is seen during the day: the later the measurement, the lower the response. Leaves from plants grown under mobile lamps, however, maintained a high response during the afternoon, decreasing at the end of the natural light period (Fig. 2). This decrease of the light response could be due to feedback inhibition, caused by the lack of sinks on a plant with only two very small (<5 cm) shoots. Since the total daily light integral of mobile and static lighting was equal, the difference between mobile and static lighting is not a simple matter of source-sink relations, and thus can not easily be explained.

When the light response curves were measured on leaves of harvestable stems, no decrease during the day was seen; for both treatments the light response was equal, and remained high during the whole natural light period. Since the majority of the measurements showed similar results for mobile- or static-lighted roses we conclude that the overall light response of both treatments is the same.

When a single mobile light pulse was given in the measuring cuvette the induction of the photosynthesis was equal in leaves from stems grown under mobile and static lighting (Fig. 3). Therefore the theory that mobile lighting has a positive effect on the induction of photosynthesis by the same mechanism as used by sun-fleck leaves could not be confirmed.

The heating of the plant by the passing mobile lamp has been measured with infrared cameras during the night. The leaf temperature of plants under static lighting was constant, the leaf temperature right under the mobile lamps increased with 2°C during the light pulse, and decreased immediately after the lamp had passed. This indicated that stomata opening was not rapidly influenced by the light pulse, as there was no extra decrease of the leaf temperature after the pulse, as could be expected when stomata had remained open after the pulse. Thus, the hypothesis that a wider opening of the stomata by the light pulse would increase the uptake of CO₂ could not be confirmed either.

The growth simulation with the INTKAM model was carried out using several mobile light regimens for the synchronous plants only. When lamp speed was halved or doubled, no differences in production were simulated, since the daily light integral was the same. When lamp speed was maintained, but lamp capacity was doubled, an increase of production was generated, however, it was less than doubled. Similarly differences in yield were not observed with a two fold increase of light -intensity using static lamps. However, when a combination of mobile and static lighting was simulated an increased production was seen, in accordance with the calculated light sum. When the production of several mobile, static and combination scenarios was simulated and plotted against the calculated absorbed PAR light integral, a classic growth-response curve is seen (Fig. 4), but no difference in growth reaction could be found between mobile or static lighting.

The fact that the observed production of the traditional crop with mobile lamps was lower than with fixed lamps differs from the above described simulation results. This is probably due to the fact that the simulation has been carried out with the synchronous crop, in which always two shoots per plant are allowed to develop. Thus the only way of changing the production level in this crop is by changing stem weight, and these possibilities probably are limited.

Since mobile lamps do not give an enhancement of the production per installed Watt lamp capacity, and since extra investments are needed for installation of mobile lighting, it is not economically feasible to invest in this system of greenhouse supplemental lighting.

Literature Cited

Chazdon, R.L. and Pearcy, R.W. 1991. The importance of sunflecks for forest understory plants. *BioSciences* 41:760-766.

Tables

Table 1. Number of rose stems per m² harvested during the experiment. Data are given for the traditional crop only. Treatments that are not significantly different (linear regression) are marked with equal symbols.

	Low light (1-3 mol day ⁻¹)	High light (3-5 mol day ⁻¹)	Mean
Mobile lamps	41 a	47 a	44 a
Static lamps	48 ab	57 b	53 a
Mean	39 a	44 b	

Table 2. Total fresh weight per m² of rose stems harvested during the experiment.

		Low light (1-3 mol day ⁻¹)	High light (3-5 mol day ⁻¹)	Mean
Traditional	Mobile lamps	1538 bcd	1538 bcd	1638 b
	Static lamps	1826 d	1826 d	2054 c
Synchronous	Mobile lamps	1143 a	1143 a	1220 a
	Static lamps	1235 ab	1235 ab	1326 a
Mean		1386 a	1386 a	

Figures

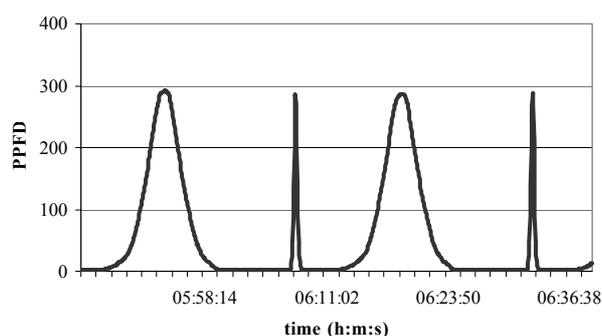


Fig. 1. Light intensity ($\mu\text{mol m}^{-2} \text{s}^{-1}$) at rooting medium level, measured right under a mobile lamp.

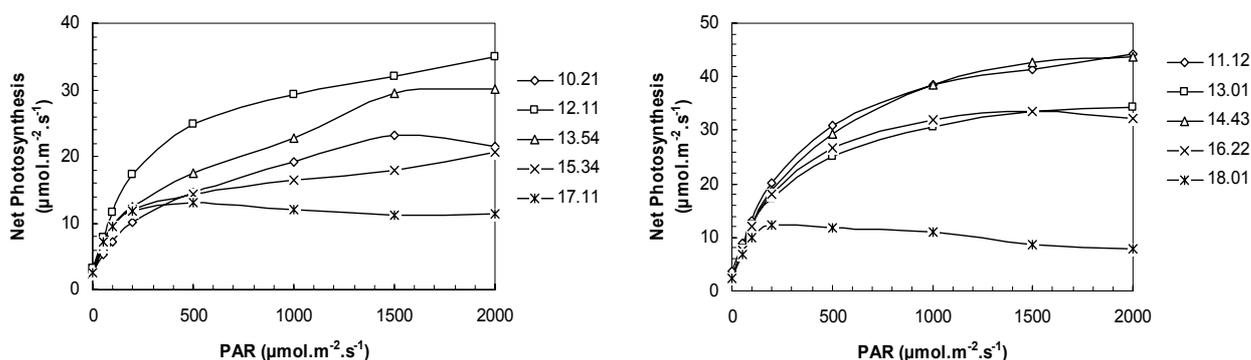


Fig. 2. Light response of leaves from bent stems of the synchronous crop grown with static (left) or with mobile (right) lamps. Time of the day at the end of one series is indicated in the legend.

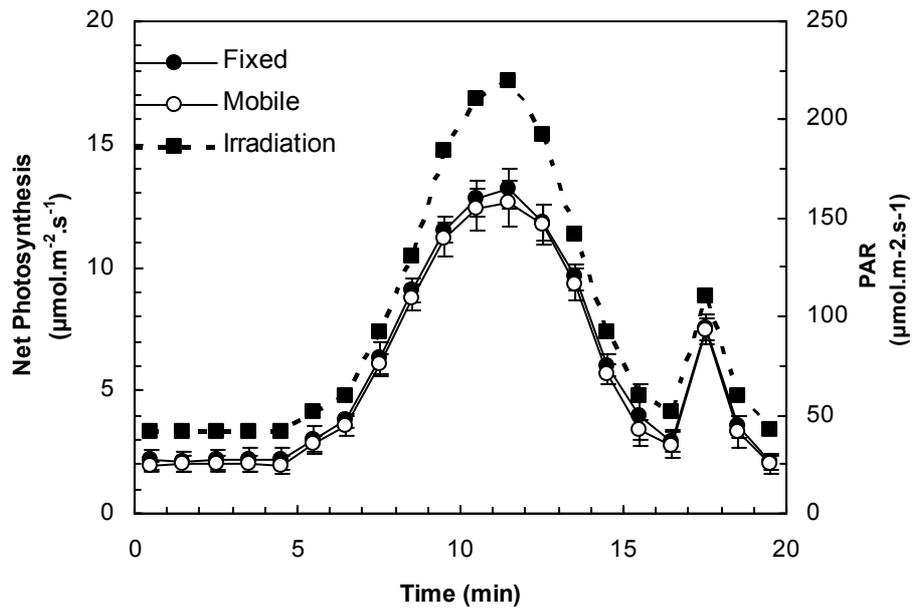


Fig. 3. Induction of the photosynthesis on leaves grown with mobile or static lighting. Means and standard errors of five measurements are given.

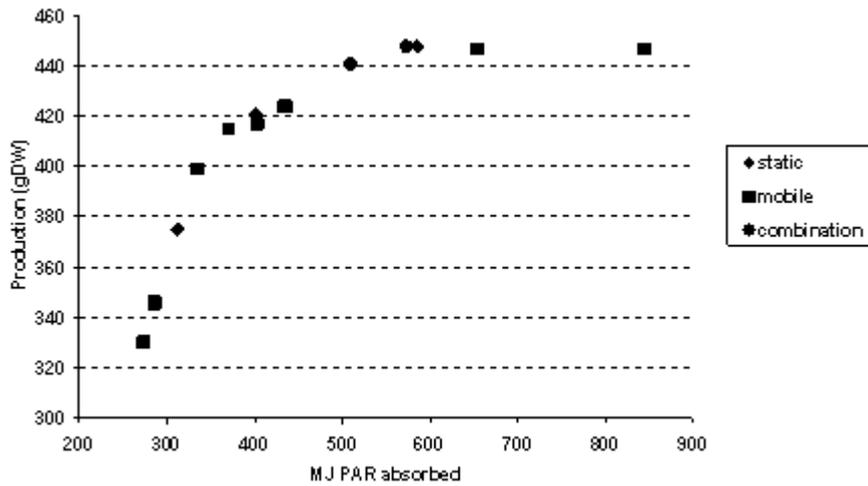


Fig. 4. Predicted production of stems (g DW) against the calculated amount of absorbed PAR light during a period equal to the experiment.

