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Interacting effects of temperature integration and light intensity on growth and development of single-stemmed cut rose plants

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Abstract

Energy conservation in horticulture can be achieved by allowing temperatures to fluctuate within predefined bandwidths instead of using rigid set points for heating and ventilation. In temperature integration, plants are supposed to compensate effects of temporarily deviations of the average temperature some time later by deviations in the opposite direction. However, little is still known on the effects of integration periods exceeding 1 day. In this study, effects of temperature integration on growth and development of single-stemmed cut rose plants were determined. Pruned rose shoots were placed in climate chambers in which light levels switched daily (2 days integration period) or weekly (14 days integration period) from high light intensity (300 μmol m^{-2} s^{-1}) to low light (150 μmol m^{-2} s^{-1}). Temperatures were kept continuously at 20 °C (control) or changed with the light intensity (phase, high temperature at high light intensity, low temperature at low light intensity) or changed opposite to the light intensity (counter phase). Bandwidths of temperature integration were 0, 6 or 10 °C. Under these conditions, buds grew out to harvestable shoots in approximately 45 days. At both integration periods, shoot length was significantly reduced with increasing bandwidths of temperature integration. Shoot dry weights were reduced when a bandwidth of 10 °C was applied. At both integration periods, rates of photosynthesis were primarily determined by light intensity. However, in the counter phase treatments, photosynthesis rate at high light and low temperature was reduced compared to the high light condition of the control. Under these conditions, starch content increased to approximately 10%, suggesting a feedback inhibition of the rate of photosynthesis. However, this did not (yet) affect plant growth or development.

Keywords: *Rosa*; Stem length; Development rate; Photosynthesis; Starch

1. Introduction

Greenhouse climate is commonly controlled by rather rigid set points for heating and ventilation. When non-fixed set points would be used, heating can be shifted to times when the heat loss factor is reduced and this would reduce energy consumption (Körner and Challa, 2003). Allowing temperatures to fluctuate within predefined bandwidths with a fixed period in which temperature deviations should be compensated, is called temperature integration. Temperature integration makes use of the ability of plants to react to an average temperature during a certain period of time. Temporary deviations of the average temperature can be compensated some time later by deviations in the opposite direction. Growth and development of a number of horticultural crops was found to react primarily to the average temperature, whereas the exact course of temperature during 24 h had minor effect (Bakker and Van Uffelen, 1988; De Koning, 1988; Rijsdijk and Vogelezang, 2000). Still little is known on temperature integration with periods longer than 1 day. For tomato (Hurd and Graves, 1984; De Koning, 1990) and rose (Buwalda et al., 1999) it was shown to be possible to integrate temperature over several days without affecting growth and production. Dieleman et al. (2005) briefly described a reduction in final rose stem length at bandwidths of 6 and 10 °C.

Plant growth is determined by assimilate production and use of these assimilates. Assimilates are produced in the process of photosynthesis, at a rate primarily determined by light and carbon dioxide level, more or less instantaneously. Temperatures within ranges of 17–25 °C hardly affected photosynthesis rates. The processing of assimilates is determined by the average temperature over a longer interval of time. The combination of time scales of assimilate production and processing most likely determines the plants capacity to

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integrate temperature over a certain time interval (Körner, 2003). All plants have the ability to store a temporarily surplus of assimilates in an assimilate buffer of non-structural carbohydrates such as sugars and starch. For an optimal growth and development, it is important that this buffer has a more or less constant content (Seginer et al., 1994). A level of carbohydrates that is too high might cause a decrease in production by feedback inhibition of the photosynthesis (Foyer, 1988), whereas exhaustion of the buffer slows down plant growth and development. This implies that for an optimal growth, temperatures averaged over a certain period should be attuned to the light integral in the preceding period. Indeed, in young cucumber plants, low night temperatures were found to affect plant growth much less when applied after a dull day than after a bright day (Challa and Brouwer, 1984). Also in ornamental crops, favourable effects on plant growth and quality were described when average temperatures were positively related to the light intensity (Liu and Heins, 1998; Ottosen et al., 2005).

In this study, effects of temperature integration on the growth and development of single-stemmed cut rose plants were determined. To determine the interaction of light and temperature in this process, in some of the treatments temperature levels were positively adjusted to the light intensities, and in other treatments temperature levels opposed the light intensity. To explain possible effects of the positive or negative adjustment of temperature to light intensity, leaf photosynthesis and leaf starch contents were measured.

2. Materials and methods

Rooted rose cuttings 'Red Berlin' on rockwool were obtained from a commercial grower and placed in a climate chamber at a temperature of 20 °C, light intensity of 280 μmol m^{-2} s^{-1} during 16 h, RH of 70% and CO_2 concentration of 370 ppm. Plants were irrigated with nutrient solution containing 11.25 mM NO_3, 1.25 mM SO_4, 1.25 mM H_2PO_4, 3.25 mM Ca, 4.5 mM K, 1.5 mM Mg and 1.0 mM NH_4 as well as the required trace elements (EC = 1.5 mS cm^{-1}). When the primary shoots were in the harvestable stage, they were cut above the second five-leaflet leaf. Treatments started at this moment by transferring the plants to five climate chambers with different light and temperature regimes as indicated below.

In all treatments light levels switched daily or weekly (depending on the integration period) from high light intensity (300 μmol m^{-2} s^{-1}) to low light intensity (150 μmol m^{-2} s^{-1}) by dimming the lamps (Philips TLD, 50W, The Netherlands). Temperatures were kept continuously at 20 °C (control) or changed with the light intensity (phase, high temperature at high light intensity, low temperature at low light intensity) or changed opposite to the light intensity (counter phase, low temperature at high light intensity, high temperature at low light intensity). Bandwidth of temperature integration was 0 °C (20 °C continuously), 6 °C (17–23 °C) and 10 °C (15–25 °C). In all treatments, VPD was kept at 7 mbar, photoperiod was 16 h and CO_2 concentration was maintained at 370 ppm.

In the experiments, two integration periods were used: 2 days (1 day high temperature, 1 day low temperature) and 14 days (1 week high temperature, 1 week low temperature). In order to prevent effects of starting with high or low temperatures, all treatments started once with high light intensities and once with low light intensities.

Experiments were set up as split-plot with light intensity—temperature treatment at whole plot level and start levels of light intensity and temperature at sub plot level, and were performed twice. Significance of the effects was tested with ANOVA followed by a Student's *t*-test ($P = 0.05$).

During the experiments, only the uppermost bud was allowed to grow out. All other shoots were removed. Shoot length of six plants per treatment was measured two to three times per week. Shoot development was recorded as the number of days until bud break (shoot length 1.5 cm) and harvestable shoot (sepals down). After 42 days, another six plants per treatment were harvested destructively and dry weights were determined. Each experiment lasted 8 weeks.

In the treatments 20 °C continuously and 15–25 °C phase and counter phase, net leaf photosynthesis rate was measured with a portable photosynthesis system (LC Pro, ADC, UK). Photosynthesis was measured at the top leaflet of the uppermost fully expanded leaf of six plants. Measurements were performed under the same conditions in the leaf chamber (light intensity, temperature, VPD and CO_2 concentration) as in the climate chamber, thereby measuring actual photosynthesis. At the 2 days temperature integration treatments, measurements were performed on two consecutive days with different conditions at the end of the experiment. At the 14 days temperature integration treatments, measurements were performed during the last 2 weeks of the experiments. Under the different conditions, photosynthesis was determined at days 1, 3 and 7. Since data of days 1, 3 and 7 did not differ significantly, average data are presented in this paper. After the photosynthesis measurements, at approximately 15:00 h, the top leaflets were collected, frozen in liquid nitrogen and freeze-dried. Starch contents were determined enzymatically (Boehringer, Mannheim, Germany) as described by De Groot et al. (2002).

3. Results

3.1. Integration period of 2 days

As the bandwidth of temperature integration increased, final shoot length was significantly lower (Fig. 1A). The decrease in shoot length was due to both a decrease in the number of leaves on the stem as well as the internode length. The average number of leaves on the stem decreased from 19.3 to 19.0 and 17.4, respectively, at bandwidths of 0, 6 and 10 °C. The internode length shortened from 3.5 to 3.3 and 3.1 cm, respectively, at bandwidths of 0, 6 and 10 °C. At a certain bandwidth of temperature integration, phase and counter phase treatments did not differ significantly in shoot length (Fig. 1B).

The period between pruning and bud break was 8 days for all treatments (data not shown). The interval between cutting and harvestable stage decreased with 1 or 3 days, respectively, at 6