Effects of Temperature Integration on Growth and Development of Roses

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Abstract

Dutch horticulture aims at a reduction of the energy use in greenhouses by 65% in 2010 compared to 1980. When temperature integration is applied, temperatures may be reduced, as long as they are compensated by higher temperatures within a pre-set time span. Applying temperature integration without adverse effects on plant growth requires knowledge about critical temperatures. In this study, effects of temperature integration with bandwidths of 0, 6 and 10 °C (average temperature of 20 °C) and integration periods of 2 and 14 days on rose plants were investigated. Shoot lengths at the harvestable stage were reduced with increasing bandwidths. This reduction in shoot length became stronger as the integration period increased. The developmental rate of rose shoots to the harvestable stage was not affected by temperature integration. Shoot fresh weight decreased at a bandwidth of 10 °C, but not at a bandwidth of 6 °C. For the application of temperature integration in the practice of cut rose growing, shoot length development is the most critical process, since it partly determines the price of rose stems. If a certain reduction in stem length is acceptable to commercial rose growing, temperature integration with a bandwidth of 6 °C can be applied even at longer integration periods without affecting the developmental rate and shoot weight.

INTRODUCTION

In Dutch horticulture, two major developments emphasised the importance of energy consumption. First, in 1997, Dutch horticulture and government agreed to improve the energy efficiency of greenhouse production by 65% in 2010 compared to 1980. Energy efficiency, m^3 gas used per unit of product, can be enhanced by increasing production. However, since the energy standards in legislation are to be set per unit area, the focus is being laid on a reduction in absolute energy consumption to improve the energy efficiency. Furthermore, the Dutch energy market for growers has been liberalised since 2002. This free market implies that growers do not pay a fixed price per m^3 natural gas anymore, but that the price is primarily determined by the maximum supply capacity of the gas contract. Therefore, since 2002 it has become more important to reduce peaks in energy use. A large part of the amount of energy used in greenhouses serves to maintain the (fixed) temperature set points. If growers would allow temperatures to fluctuate, depending on the energy needed to maintain the temperature at the set point, energy conservation would be possible. In practice, this already occurs to some extent. Some growers allow reduced temperatures to occur when the desired temperature cannot be realised due to the limitations of the maximum supply capacity of their contract.

When those lower temperatures are compensated by higher temperatures when energy losses from the greenhouse are limited, this is called temperature integration. Temperature integration is based on the plant's ability to react primarily to the average temperature rather than to the exact 24 h temperature course (Bakker and Van Uffelen, 1988; De Koning, 1988; Rijsdijk and Vogelezang, 2000). Calculations and experiments with temperature integration show that 5-15% energy conservation can be realised without affecting plant growth and production (Hurd en Graves, 1984; Bailey & Seginer, 1989; Buwalda et al.,1999; Körner and Challa, 2003; Elings et al., 2005). For a band width of 2 °C and integration periods of 1 or 3 days, a reduction in energy use of 5.5

respectively 6 % was calculated for a year round grown commercial rose crop (Dueck et al., 2004).

The possibilities to conserve energy by temperature integration become greater with an increasing integration capacity of the crop. The integration capacity is determined by the bandwidth of the deviation from the average temperature as well as the period during which this deviation occurs (integration period). To apply temperature integration in practice, effects of both bandwidth and integration period for development and production of the crop have to be known. Furthermore, interaction with the developmental stage of the crop has to be taken into account. Although Van de Braak and De Zwart (2001) have shown that the bandwidth primarily determines the energy conservation that can be realised with temperature integration, only little is known about the critical temperature limits for different crops and their developmental stages. In this study, limits of temperature integration are investigated. Under conditions with varying light intensities, temperature integration with bandwidths of 0, 6 and 10 °C was applied with integration periods of 2 and 14 days. Effects on stem length, shoot weight and developmental rate of the cut rose cultivar Red Berlin were studied.

MATERIALS AND METHODS

Rooted rose cuttings cv Red Berlin on rockwool were obtained from a commercial propagator and placed in a climate chamber at a temperature of 20 °C, light intensity of 280 µmol m^{-2} s^{-1} during 16 h and RH of 70%. 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 en 1.0 mM NH_4 as well as the required trace elements (EC = 1.5 mS cm^{-1}). The treatments started when the primary shoots were in the harvestable stage and had been pruned above the second five-leaflet leaf.

In all treatments, light level varied per day or per week. This implies that plants were kept at high light intensity (300 µmol m^{-2} s^{-1}) for one day or one week (depending on the integration period) and at low light intensity (150 µmol m^{-2} s^{-1}) for the other day or week. Temperatures were kept at 20 °C (control) or changed with light intensity. Bandwidths were 0 °C, 6 °C (temperatures alternately 17 and 23 °C) or 10 °C (temperatures alternately 15 and 25 °C). The vapour pressure deficit was kept at 7 mbar in all treatments. Two integration periods were used: 2 days (1 day high temperature and high light intensity, 1 day low temperature and low light intensity) and 14 days (1 week high temperature and light intensity, 1 week low temperature and light intensity). Experiments were performed twice (in time). In the first experiment, all treatments started with high light intensities and high temperatures, in the second experiment, all treatments started with low light intensities and low temperatures. The experiments were set up as split-plot, with temperature treatments as main plot and starting temperatures as subplot. Per integration treatment and replicate, temperature treatments were allocated randomly to the 5 climate chambers used. All measurements were performed on 6 plants per treatment. Significance of treatments was tested with ANOVA (P=0.05), followed by Student's t-tests.

During the experiments, shoot development was recorded as the number of days from cutting back the primary shoot until the newly developed shoots reached developmental stage 1 (bud break, shoot length 1.5 cm), stage 2 (flower bud visible) and stage 3 (harvestable shoot, sepals down). At the harvestable stage, shoot length was recorded. Every fortnight, 6 plants per treatment were harvested destructively and fresh weights were determined until the experiment was terminated after 8 weeks.

RESULTS

Integration Period of 2 Days

As the bandwidth of temperature integration increased, shoot length at the harvestable stage was significantly reduced (Fig. 1). Shoot length at 17-23 °C did not differ significantly from that at 20 °C, but the shoot length at 15-25 °C was significantly reduced. On average, stems were 9% shorter in the 17-23 °C treatment (bandwidth 6 °C) and 21% shorter in the 15-25 °C treatment (bandwidth 10 °C) than in the control.

The development of a rose shoot can be divided into three stages: bud break, visible flower bud formation and harvestable stage. The time between pruning the primary shoot and bud break was 8 days for all treatments (data not shown). The period from pruning to the harvestable stage was slightly reduced with increasing bandwidth of temperature integration (Table 1). However, these differences were not statistically significant. The time between visible flower bud formation and harvestable stage remained more or less constant (data not shown). The plants were destructively harvested at 2-weekly intervals. Fresh weights measured 2, 4 and 6 weeks after pruning the primary shoot just prior to the harvestable stage did not differ significantly between treatments (data not shown).

Statistical analysis of the results showed that the starting temperature did not affect significantly (P=0.05) shoot length, developmental rate and fresh weights.

Integration Period of 14 Days

Shoot length was significantly affected by the bandwidth at an integration period of 14 days. With increasing bandwidths, stems became significantly shorter (Fig. 2). Stem lengths were reduced by 12% at a 6 °C bandwidth and by 26% at a 10 °C bandwidth compared to the control treatment.

The average time between pruning the primary shoot and bud outgrowth to 1.5 cm varied between the temperature treatments in the range of 6 to 10 days. Bud break was primarily affected by temperature in the first week after cutting, i.e. significant effect of starting temperature. At higher temperatures, buds broke significantly earlier. The effect of the earlier bud break made itself felt in the time to visible flower bud and the time to the harvestable stage. They were both significantly shorter when the plants were placed at high temperatures immediately after cutting back (data not shown). Time between pruning and the harvestable stage of the flowering shoot was not significantly influenced (Table 2).

At 2-weekly intervals, plants were harvested destructively. The course of fresh weight increase is depicted in figure 3. Plants reached the harvestable stage between 45 and 50 days, depending on the temperature treatment. At this stage, axillary buds on the top of the shoot started to break. These were removed as soon as they appeared. Therefore, plants that reached harvestable stage earlier were hampered more severely in their weight increase. This determined the course of shoot weight between 42 and 56 days. As the temperature bandwidth increased, the fresh weight of the shoots 42 days after pruning decreased. This decrease was only significant for a bandwidth of 10 °C (Fig. 3).

DISCUSSION

The results of temperature integration experiments with integration periods of 2 and 14 days and bandwidths of 0, 6 or 10 °C were described in this paper. The main result of this study is that shoot lengths of rose stems were reduced with increasing bandwidths at both integration periods. At a bandwidth of 10 °C stems were significantly shorter than in the control treatment (20 °C continuously), in contrast to a bandwidth of 6 °C. For commercial practice, stem length is an important characteristic, since higher prices are paid for longer rose shoots. When roses are grown under constant temperature, final shoot length becomes shorter at increasing temperatures (De Vries et al., 1986; Van den Berg, 1987; Marcelis-van Acker, 1994). This implies that the response of rose shoot length to fluctuating temperatures (at an average temperature of 20 °C) resembled the reaction to increased temperatures. Temperatures above 20 °C affected shoot length more strongly than did temperatures below 20 °C, resulting in a non-linear response to temperature. When temperature integration is applied in commercial practice, it might therefore be necessary to lower the average diurnal temperature, in order to diminish effects on shoot length.

In the development of a rose shoot, 3 stages can be distinguished: bud break, visible flower formation and development to harvestable shoot. In our experiments, the time between cutting and bud break in the 2 day temperature integration treatments were not affected by the treatments. In the 14 day temperature integration treatments, the rate of bud break was determined by the temperature during the first week after cutting back. At a temperature of 25 °C in this week buds broke in 6 days. At temperatures of 15 °C, it took 10 days until bud break, which is in agreement with results of De Vries et al. (1982), Van den Berg (1987) and Marcelis-van Acker (1994).

With increasing bandwidths of temperature integration, the time between pruning and the harvestable stage decreased by a few days. This effect was statistically not significant. For the rose cultivars Frisco and Madelon however, Buwalda et al. (2000) did find a significantly faster development to the harvestable stage occurred at an integration period of 12 days and a bandwidth of 4 °C compared to a constant temperature of 18 °C. That rose cultivars differ in their reactions to temperature integration is also clear from the fact that Buwalda et al. (2000) found no significant effects of the temperature integration treatments on the length and shoot weight of Frisco, but that they led to shorter and lighter shoots of Madelon. In our experiments, temperature integration with an integration period of 2 days did not affect the shoot weight of Red Berlin. On the contrary, at an integration period of 14 days, the shoot weight decreased at increasing bandwidths of temperature integration.

Our results show that temperature integration with an integration period of 2 days is possible if a certain reduction in stem length is acceptable. Integration periods longer than these can be applied without affecting shoot weight if the bandwidth is restricted to 6 °C.

CONCLUSIONS

For the application of temperature integration in the practice of cut rose growing, shoot length development is the most critical process. An important reason for this is that the price of rose stems of a cultivar is higher for longer stems. Our results show that with increasing temperature integration bandwidths, shoot length decreases. This decrease is stronger at longer integration periods. If a certain reduction in stem length is acceptable to commercial rose growing, temperature integration with a bandwidth of 6 °C can be applied without effects on developmental rate and shoot weight, even for longer integration periods.

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Tables

Table 1. Time from pruning to harvestable stage for the temperature treatments with bandwidths of 0 °C (constant 20 °C), 6 °C (alternately 17 and 23 °C) and 10 °C (alternately 15 and 25 °C) at a 2 day integration period (n=24).

Treatment	**Time to harvestable stage (days)**
20 °C	46
17-23 °C	45
15-25 °C	43
LSD (P=0.05)	6

Table 2. Time from pruning to harvestable stage for the temperature treatments with bandwidths of 0 °C (constant 20 °C), 6 °C (alternately 17 and 23 °C) and 10 °C (alternately 15 and 25 °C) at a 14 day integration period (n=24).

Treatment	**Time to harvestable stage (days)**
20 °C continuously	50
17-23 °C	46
15-25 °C	45
LSD (P=0.05)	6

Figures

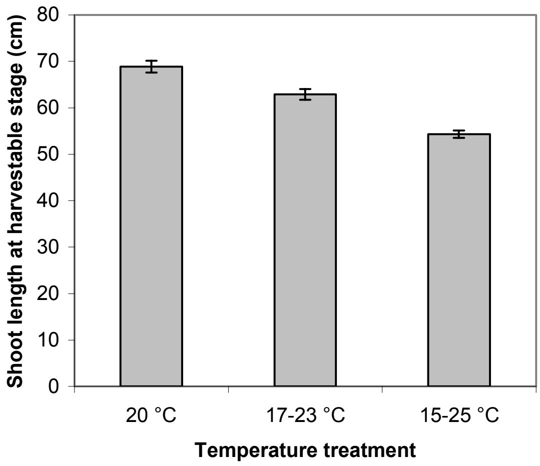

Fig. 1. Length of rose shoots at the harvestable stage (mean ± standard error of mean) for the temperature treatments with bandwidths of 0 °C (constant 20 °C), 6°C (alternately 17 and 2 3°C) and 10 °C (alternately 15 and 25 °C) at a 2 day integration period (n=24).

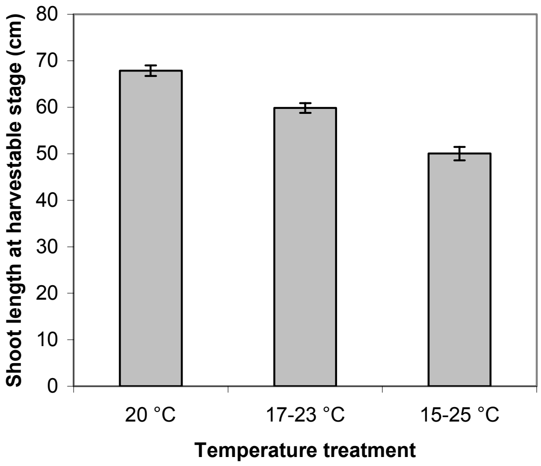

Fig. 2. Length of rose shoots at the harvestable stage (mean ± standard error of mean) for the temperature treatments with bandwidths of 0 °C (constant 20 °C), 6°C (alternately 17 and 23°C) and 10 °C (alternately 15 and 25 °C) at a 14 day integration period (n=24).

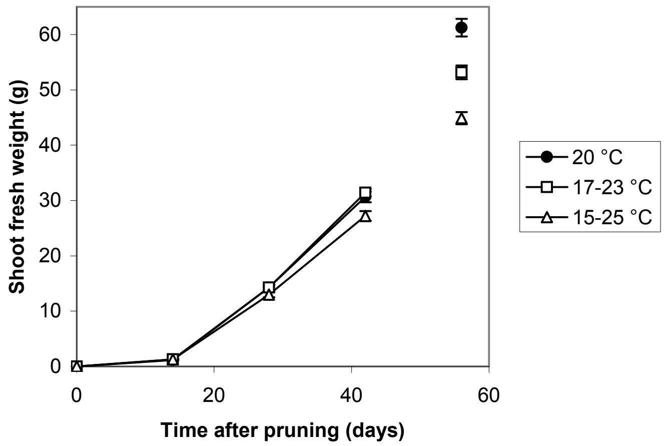

Fig. 3. Time course of shoot fresh weight (mean ± standard error of mean) for the temperature treatments with bandwidths of 0 °C (constant 20 °C), 6 °C (alternately 17 and 23°C) and 10 °C (alternately 15 and 25 °C) at a 14 day integration period.