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Cultivar Differences in Temperature Demand of Cut Chrysanthemum

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Abstract

The influence of temperature on dry matter production, growth analysis parameters, stem length, number of leaves and flower characteristics of 25 cut chrysanthemum cultivars was investigated. Plants were grown in the greenhouse at two constant temperatures setpoints, 16 and 20ºC. Destructive measurements were carried out at the end of the long day period and at flowering. During the long day period relative growth rate was increased at high temperature for all cultivars due to an increase in net assimilation rate and for a few cultivars also by an increase in leaf area ratio. Significant temperature x cultivar interactions were only present for stem length, number of leaves and leaf area ratio. For all other characteristics there were clear differences between the two temperature treatments and the cultivars. Depending on the cultivar, flowering was delayed by 4 to 13 days when cultivated at low temperature. At flowering, a significant temperature x cultivar interaction was observed for all measured or calculated parameters. For example, for one cultivar both the differences in number of days till flowering and the total dry mass between 16ºC and 20ºC were small while for another cultivar there was a 34% higher dry mass at lower temperature, while the growth period was not much extended. Differences in dry mass at flowering between the two temperature treatments could be explained by differences in growth rate. These data show good possibilities for breeding for low temperature demand in cut chrysanthemum.

INTRODUCTION

Year round production of high-quality chrysanthemum can be achieved in greenhouses by varying the greenhouse climate conditions (Carvalho and Heuvelink, 2001). In The Netherlands this means that during the winter months the growers have to heat their greenhouses to keep the temperature high. This leads to high costs and environmental problems, resulting from the emission of CO_2. Therefore an agreement was made between the Dutch greenhouse growers and the government to increase energy efficiency by 65% in 2010 compared to 1980. Energy efficiency can be increased either by increasing the production per m^2 or by a reduction in the amount of energy used per m^2 of greenhouse. Besides several technical measures, an increase in energy efficiency could be reached when temperatures in the greenhouse would be reduced, achieving the same production levels. Model calculations show that decreasing the heating set-point from 20 to 18°C would lead to energy saving of 20% on annual basis (Körner, 2003). It is therefore important to develop chrysanthemum cultivars, which have a broader or lower temperature optimum.

However, lower temperatures will affect growth and development in chrysanthemum. Leaf unfolding rate is lower (Larsen and Hidén, 1995) and flowering is delayed (De Jong, 1978, Adams et al., 1998) at sub-optimal temperatures, although the length of delay is cultivar dependent (De Jong, 1978, De Lint and Heij, 1987, Hidén and Larsen, 1994). As in chrysanthemum temperature effect on time to flowering is so big, optimal temperature is usually considered as the temperature at which the plants flower the earliest. The effects of temperature on biomass production of chrysanthemum are however less clear. At flowering, either a higher (Lepage et al., 1984), equal (Carvalho, 2003) or a lower (Karlsson and Heins, 1992) plant dry weight at sub-optimal temperature has been recorded. These different responses could result from different growth conditions but also cultivar differences might play a role.

For ornamental crops like chrysanthemum there could be large cultivar differences in growth related traits, as selection has not only taken place on the basis of rapid growth and high yield but also on flower, stem and leaf characteristics and vase life. This variation could be used by the breeders when breeding for cultivars adapted to sub-optimal temperatures.

The present work aims at determining possible differences in growth and development among 25 cultivars of chrysanthemum at two temperatures. Furthermore we elaborate on what physiological and morphological parameters could explain these possible differences.

MATERIALS AND METHODS

Plant Material and Growth Conditions

The experiment was carried out in four compartments (12.8m x 12.0m) of a multispan Venlo-type glasshouse at Wageningen University, The Netherlands (lat. 52°N). Each compartment contained 8 parallel soil beds (1.125m x 10.25m) of which the outer two were used as borders. Block rooted cuttings of 25 chrysanthemum cultivars (Feeling Green, Grand Pink, Greenbird, Mundial, Reagan Improved, Shining, Spoetnik, Supernova, Tiger, Universe, Voyager, Woodpecker; Fides Goldstock Breeding, Maasland, the Netherlands and Anastacia, Annecy, Beverly, Biaritz, Bradford, Cayenne, Delianne, Dublin, Granada, Hastings, Managua, Orinoco, Zembla; Deliflor, Maasdijk, the Netherlands) were planted on the 27th of November 2002 in parallel soil beds (1.125m x 10.25m) at a plant density of 48 plants per m^2.

In two compartments the heating set-point for both day and night was 16°C (low temperature treatment, LT) whereas this was 20°C (high temperature treatment, HT) in the other two compartments. Ventilation setpoints were 1ºC above heating setpoints. During the first three weeks after planting, plants were grown under long day (LD) conditions, followed by a short day (SD) period up to harvest. The apical flower was removed in an early stage. High pressure sodium lamps (HPS, Philips SON-T Agro, 44 μmol $m^{-2}s^{-1}$ PAR) were kept continuously on during the day hours of the LD (19 hrs, from 5:00 to 24:00) and SD period (9 h 30 min., from 7:30 to 17:00). Pure CO_2 was supplied when CO_2 concentration in the greenhouse was below 350 μmol mol^{-1} and dosing stopped at 420 μmol mol^{-1}. Greenhouse temperature was automatically recorded every 5 minutes using a commercial computer system (Hoogendoorn, Vlaardingen, The Netherlands). The greenhouse mean 24 h temperatures were 16.5°C (LT) and 20.1°C (HT).

Measurements

Destructive measurements were carried out at planting, start of the SD period and at final harvest. Initial stem and leaf fresh and dry weight (ventilated oven, 105°C for at least 15 hours) were measured on 10 plants per cultivar. Final harvest occurred when plants had at least 3 flowers fully open. This stage was reached at different times depending on the cultivar and temperature. Per experimental plot five plants were harvested, leaving two rows of border plants between cultivars and harvests. Stem, leaf and flower fresh and dry weight, number of leaves on the main stem, number of flowers and stem length were determined. Leaf area and individual flower area of the first flower (LI-COR Model 3100 Area Meter, USA) were determined. No root measurements were done. From the values of leaf area and dry weight of leaves, stems and flowers the following growth parameters were calculated:

1) Relative growth rate (RGR) = $(\ln W_{SD}-\ln W_S)/(t_{SD}-t_S)$
2) Leaf area ratio (LAR) = $((LA_S/ W_S)+ (LA_{SD}/ W_{SD}))/2$
3) Net assimilation rate (NAR) = $(W_{SD}-W_S)/(t_{SD}-t_S)*(\ln LA_{SD}-\ln LA_S)/(LA_{SD}- LA_S)$
4) Absolute growth rate (GR) = $(W_F-W_{SD})/(t_F-t_{SD})$

where W, LA and t represent the total dry weight, leaf area and time, respectively. The subscripts S, SD and F represent the start of the experiment, start of the SD treatment and flowering, respectively.

Statistical Design and Analysis

Each compartment was split up in two blocks. Data were analysed as a split plot design with four replications for temperature. Temperature was the main factor and cultivar the split factor.

Analysis of variance was conducted. Mean separation was done by calculation of the Least Significant Difference (L.S.D.) based on Student t-test (P=0.05). The statistical software package Genstat 6 was used.

RESULTS

Effect of Temperature during LD Period

Both temperature and cultivar had a strong influence on total dry weight (P<0.001), but there was no interaction (P=0.993) between these two factors. After three weeks of LD plants grown under HT where significantly heavier (24%) than plants grown under LT. Cultivar Grand Pink produced the heaviest plants (2.03g) while Supernova produced the lightest plants (1.25g). Also for stem (P=0.868) and leaf (P=0.957) weight no interaction between temperature and cultivar was found, although both factors had individually a strong influence (P<0.001). The RGR and NAR during the LD did not show a significant interaction between temperature and cultivar, while temperature and cultivar independently had a large effect on RGR and NAR (P<0.001; Fig. 1A). RGR and NAR were 11 and 10% higher at HT, respectively. The cultivar with the highest RGR (Grand Pink) had a RGR that was 36% higher than that of the cultivar with the lowest RGR (Voyager). LAR on the other hand showed a significant interaction between temperature and cultivar (P<0.001; Fig. 1B). Six cultivars showed a significantly higher LAR at HT, two a lower LAR at HT and the other cultivars showed no response in LAR in reaction to temperature.

Although stem length was always higher at HT the response was significantly stronger in some cultivars than in others (P<0.001). The increased stem length at HT was in all cultivars caused by a higher number of internodes while in some cultivars a higher average internode length at HT played also a role.

Effect of Temperature during the SD

LT delayed flowering in all cultivars, compared to HT, but the extent of this delay differed between cultivars (Fig. 2). The delay in flowering at LT was longest for Reagan Improved (13 days) while for Supernova this delay was only 4 days. At the time of final harvest a significant interaction between temperature and cultivar was found for total dry weight (P=0.003; Fig. 3A), leaf dry weight (P=0.009), stem dry weight (P=0.002) and flower dry weight (P<0.001). Plants of 11 cultivars were heavier at LT, while for the other 14 cultivars weight was independent of the temperature at which it was grown. The GR during SD was also significantly affected by the interaction between temperature and cultivar (P<0.001; Fig 3B). One cultivar had a higher GR at HT while 8 cultivars had a higher GR at LT.

All flower characteristics were also significantly influenced by the interaction between temperature and cultivar. There were 11 cultivars that had a higher number of flowers at HT while two cultivars had a higher number of flowers at LT. For 18 cultivars the area of the first flower increased at LT. The total flower dry weight was higher at LT for 12 cultivars, while for the other cultivars there was no significant difference in total flower dry weight between the temperature treatments.

Stem length and number of leaves were influenced by the interaction between temperature and cultivar. A higher stem length at HT was recorded for 18 cultivars while one cultivar (Anastacia) was taller at LT. The final number of leaves increased at HT for 13 cultivars and was lower in one cultivar (Anastacia).

DISCUSSION

At flowering there was a large variation in growth related traits within the studied 25 chrysanthemum cultivars. This variation was not only due to differences in growth period between different cultivars and temperatures. Indeed there were clear differences in the delay of flowering at LT but increases in biomass were associated with increased growth rates during the SD period (Fig. 4). This variation in biomass production between different cultivars in response to temperature could be an explanation for the contrasting results found in previous studies by Lepage et al. (1984), Carvalho (2003) and Karlsson and Heins (1992).

At the end of the LD period there was no interaction between cultivars and temperature for dry weight and RGR. Differences in RGR can be explained either by differences in leaf area per unit plant mass (LAR) or by differences in the rate of increase in plant mass per unit leaf area (NAR). RGR seems to be more related to NAR than to LAR (Fig. 1), although taken over all cultivars there is only a poor relationship between RGR and NAR. This is a result of differences in NAR level between the cultivars. In six cultivars LAR is also responsible for the increase in RGR, but in the other cultivars LAR is either not influenced by temperature or is lower at HT. These results contradict previous results where it was found that differences in RGR between chrysanthemum cultivars where due to differences in LAR (De Jong and Jansen, 1992). Differences in RGR between species could in 80 to 90% of the cases be explained by a higher LAR and only in 10 to 20% of the cases by a higher NAR (Poorter, 1989). Also responses in RGR related to temperature are usually found to be related to LAR (Heuvelink, 1989), but for chrysanthemum an increase in RGR due to a partial reduction of the night temperature lead to a higher RGR due to a higher NAR (Parups and Butler, 1982). On the other hand an increased LAR was found with increasing temperatures between 10 and 30ºC (Acock et al., 1979).

The differences between cultivars in reaction to temperature start to occur during the SD period and are likely to be related with flower development. Bud initiation is retarded at temperatures below 20ºC (Van Ruiten and De Jong, 1984) and plants grown at LT have therefore more time to invest in vegetative growth. This can be deducted from the fact that the final leaf numbers at the end of the experiment for some cultivars were equal at both temperatures while at the start of the SD period they were higher at HT for all cultivars. This together with the longer growth period resulted in plants that were either heavier at LT or equally heavy.

At the end of the LD period stem length was increased by a higher number of internodes and for some cultivars also by a higher internode length. A higher internode length is not expected as the difference between day and night temperature (DIF) was the same in both treatments. But the higher average internode length might be a result of a lower percentage of not fully elongated internodes at LT. At flowering, when all the internodes are fully elongated, there was no difference in internode length between the treatments.

A large variation between cultivars was also present for all other measured plant characteristics, for example total plant biomass and flower number. Carvalho and Heuvelink (2003) observed a positive linear relationship between biomass and flower number, when varying plant biomass by changing plant density or light conditions. In our experiment, some cultivars showed a lower number of flowers at LT, although the plant biomass was higher. This is in agreement with Carvalho (2003), who found that at low light levels, differences in flower number and biomass due to differences in growth temperature did not fit with the earlier mentioned positive linear relationship.

In this study we make a first attempt to explain differences between chrysanthemum cultivars in temperature response. Chrysanthemum cultivars have a higher RGR during the LD at HT but as the GR during the SD period of some cultivars is higher at LT the plants will have accumulated more biomass at the end of the experiment. In terms of energy saving, growing chrysanthemum at a lower temperature is hampered by a longer cultivation period. However, as some cultivars have a higher weight at flowering at LT it

might be possible to grow these cultivars at a higher plant density to produce plants of the same final weight at lower temperatures. However to completely understand these differences in growth between HT and LT more detailed studies on contrasting cultivars with more frequent measurements are needed.

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Figures

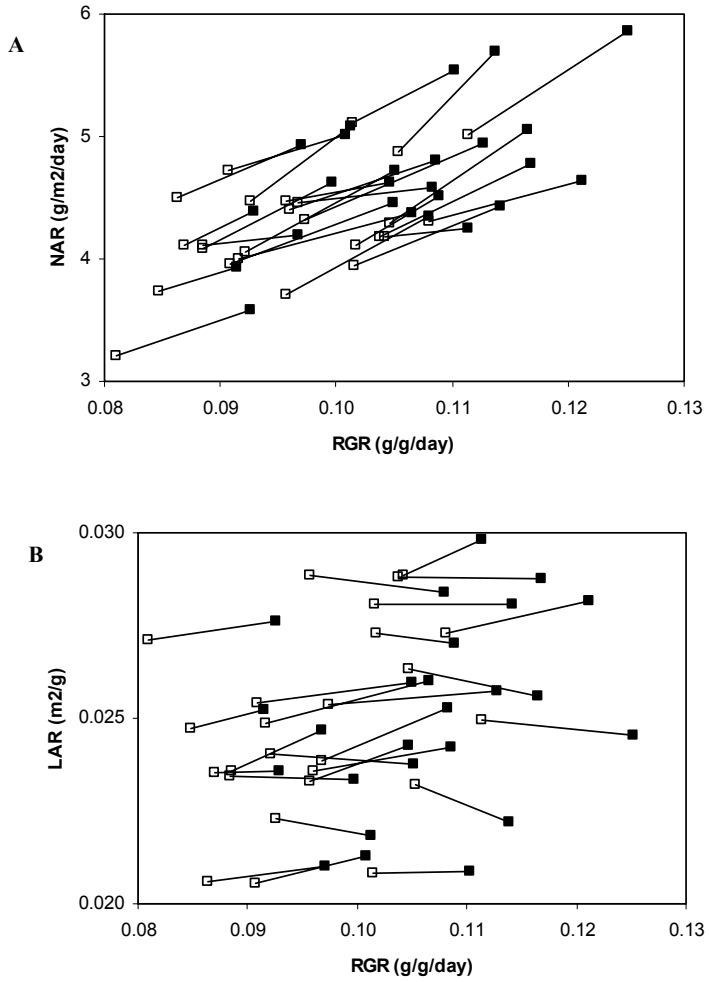

Fig. 1. Relationship between NAR and RGR (A) and between LAR and RGR (B) of 25 cultivars grown at LT (open symbols) and HT (closed symbols).

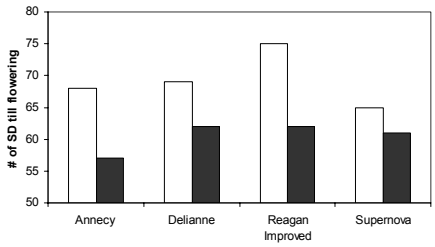

Fig. 2. The number of days after the start of the SD treatment until flowering of four contrasting cultivars at LT (white bars) and HT (black bars).

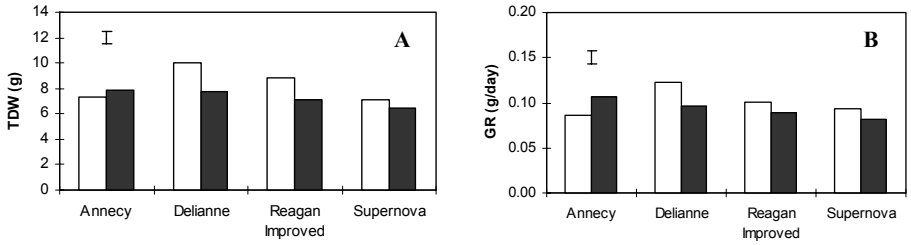

Fig. 3. Total dry weight (A) and growth rate (B) of 4 contrasting cultivars grown at LT (white bars) and HT (black bars). Vertical bars indicate least significant differences.

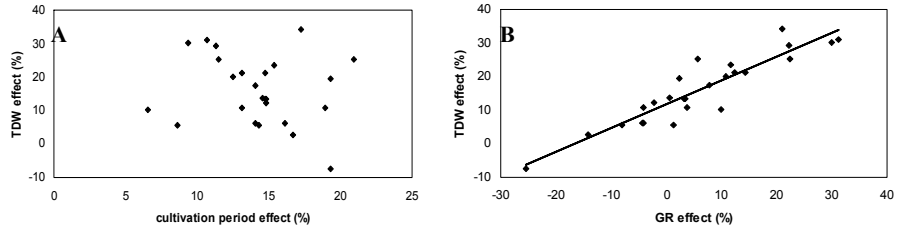

Fig. 4. The effect of the relative increase in cultivation period (A) and growth rate (B) at 16ºC compared to 20ºC on the relative increase in total dry weight. Regression line: $y = 0.71x + 11.8$, $R^2 = 0.85$.